AN ALUMINA-LITHIA-IRON OXIDE PHOSPHOR[1]

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ABSTRACT

A phosphor containing alumina, lithia, and iron oxide is described. It is efficiently excited by 2537 Å radiation, emitting a band spectrum with its energy peak at 6800 Å and half its peak energy intensity at 6520 and 7320 Å.

Silica enhances the fluorescence, with a broad composition optimum at about the ratio 1 mol alumina, 0.3 mol lithia, 0.15 mol silica, 0.002 mol ferric oxide. Firing temperatures and times are not critical, 1250°C. for 2 hours is suitable. The firing is done in open containers.

Much of the lithia may be leached from the phosphor, as by acids, without reducing the fluorescence. The leached phosphor may be reheated to at least 900°C. without impairing the fluorescence, but refiring in the 1250°C. region reduces the fluorescence to that which would be obtained by an initial firing of a batch having the composition of the leached phosphor.

INTRODUCTION

Chromium-activated alumina phosphors, both natural and synthetic, have long been known. Kröger has discussed at length various alumina-based phosphors (1). Froelich has described a manganese activated strontium aluminate (2).

However, the alumina-based phosphor described in this paper is unusual in that iron, so commonly a poison to phosphors, is an essential component. Lithia is also essential for development of the phosphor, while silica enhances the fluorescence.

PREPARATION

In the preparation of this phosphor, the batch materials used were commercial "chemically pure" grades of aluminum hydroxide and lithium carbonate, a precipitated hydrated silica containing about 9 per cent water, and a precipitated hydrated iron oxide prepared from C.P. grade reagents. According to the suppliers' analyses, the aluminum hydroxide contained 0.02 per cent iron, and the lithium carbonate contained 0.004 per cent iron. The silica was of a purity suitable for the manufacture of silicate phosphors and it was assumed that very little iron was introduced from it. The batches were mixed by pebble milling and fired at 1250°C. for two hours in open crucibles.

Preliminary developments indicated an optimum batch composition for this phosphor in about the ratio:

$Al(OH)_3$	100 g.
Li_2CO_3	15
$SiO_2 + 9\% H_2O$	6
$Fe_2O_3 \cdot 4 H_2O$	0.3

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Deviations from this composition were then made, keeping the aluminum hydroxide constant and varying singly each of the other three components. The lithia, silica, and iron oxide, respectively, were reduced to zero, to one-third, and increased to three times the quantities in the base formula. In order to obtain the lowest iron content (0.006 times the amount in the base formula), it was necessary to prepare a special aluminum hydroxide. No attempt was made to purify the lithium carbonate and silica. Assuming that the special aluminum hydroxide was free from iron, it was computed that the lithium carbonate and silica would introduce about six thousandths of the iron in the base formula. An iron variation containing nine times the base quantity was also made. These variations, with the base formula as control, were fired at 1300°C. for one hour. Brightnesses of these variations were measured and are given in Table I. In the tabulation, a compensation is made for the adventitious iron introduced from the batch materials. Firings of the group of variations were also made at 1100° and at 1200°C. for one hour and these groups showed a brightness vs. composition relation similar to the 1300°C. group although for each composition the brightness was lower at the lower firing temperatures.

TABLE I. *Influence of composition on brightness*

	% of quantity in base formula	Relative brightness
Lithia variation	0	0
	33	46
	100	100
	300	16
Silica variation	0	85
	33	85
	100	100
	300	78
Iron oxide variation	0.6	20
	12	73
	42	93
	100	100
	280	87
	800	69

It can be seen from Table I that the silica concentration is the least critical, the lithia concentration is the most critical, and that iron oxide and lithia are both essential in this phosphor. It is also apparent that the base formula is close to the optimum composition.

Firing temperatures and times are not critical. Some development of red fluorescence appeared in a small batch fired for one-half hour at 1050°C. For a one hour firing of 10 gram batches, 1300° was better than 1200°C. and 1200° better than 1100°C. for all the composition variations of Table I. A sixteen hour firing of the base formula at 1160° was equal in brightness to a one hour firing at 1300°C. Thus it appears that time and temperature are synergistic at least between 1160° and 1300°C., and that the development of this phosphor depends on solid state diffusion.

A batch of the base formula was fired in a covered crucible with a chunk of graphite, and this phosphor was of low brightness, indicating that strong reducing conditions are not desirable.

This phosphor may be strongly attacked by hot water or acids without impairing the fluorescence. For example, the phosphor was leached with an excess of 20 per cent aqueous HCl until 68 per cent of the lithia, 18 per cent of the iron, and 13 per cent of the alumina were removed. There was no significant change in the brightness, and this leached phosphor was reheated to 900°C. without appreciable change. However, on refiring the leached phosphor at 1250°C. for one hour, the brightness dropped to a value about equal to that which would have been obtained on an initial firing of a batch having the composition of the leached phosphor. Strong alkaline solutions had no noticeable effect on the phosphor.

A number of batches using substituent elements for the lithium, silicon, iron, and part of the aluminum were prepared and fired at 1250°C. The substitutions, made on a mol for mol basis, follow:

1. P_2O_5, B_2O_3, for $\frac{1}{3}$ of the Al_2O_3.
2. ZrO_2, TiO_2, SnO_2, PbO_2, for SiO_2.
3. Na_2O, K_2O, CaO, SnO, MgO, ZnO for Li_2O.
4. MnO, TiO_2, Sb_2O_3, As_2O_3, Bi_2O_3, Pb_3O_4, Co_2O_3, NiO, CuO, Ag_2O, CrO_3, for Fe_2O_3.
5. 3 mols MgO for 1 mol Li_2O.
6. 0.5 mol Na_2O + 0.5 mol K_2O for 1 mol Li_2O.

None of the substituents produced a good phosphor. Especially striking was the absence of fluorescence in all the lithia-free phosphors. With the iron substituents, some fluorescence was observable in most of the preparations. This fluorescence was undoubtedly due to the adventitious iron in the other batch materials.

PROPERTIES

The phosphor is friable, free flowing, and does not contain hard sintered particles at the firing temperatures and times given.

The fluorescence is not efficiently excited by cathode rays or by 3650 Å radiation, but 2537 Å radiation is an efficient excitant giving a quantum efficiency comparable to that of zinc beryllium silicate. The energy peak is at 6800 Å; the wave lengths at which the energy is half the peak value are 6520 and 7320 Å. No evidence of a spectral line structure was found and the emission curve is symmetrical with respect to frequency and has the general shape of the probability function.

DISCUSSION

While lithia is essential to the development of this phosphor on firing, it may be subsequently removed from the phosphor without impairing the efficiency of its fluorescence. This indicates that the lithia promotes the formation of an alumina or an alumina-iron oxide structure which is fluorescent and that lithium atoms do not play an essential part in the fluorescence.

The role of iron in this phosphor is not known. The iron may act as an absorber of short wave ultraviolet, transferring its excitation to the alumina lattice, or, more likely, the fluorescence is characteristic of the ferric iron.

Studies of the ultra-violet absorption and of the crystal structure would be of interest and would provide a sounder basis for elucidating the mechanism of fluorescence in this phosphor.

Any discussion of this paper will appear in the discussion section of Volume 95 of the TRANSACTIONS of the Society.

REFERENCES

1. F. A. KRÖGER, "Some Aspects of the Luminescence of Solids," Elsevier Publishing Company, Inc., New York (1948).
2. H. C. FROELICH (To General Electric Company) U. S. Pat. 2,392,814, Jan. 15, 1946.

TWO NEW "RED" PHOSPHORS[1]

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ABSTRACT

A short account is given of the preparation and luminescent spectral emissions of zinc barium sillicate:Mn and aluminum phosphate:Sn,Mn phosphors. Both these phosphors can give spectra with high red content under 2537 Å radiation.

GENERAL

This note gives an account of two phosphors which are new to the lamp industry and capable of emitting red fluorescent light when excited by ultraviolet radiation of 2537 Å wave length. They may, therefore, be used in the standard fluorescent lamps of today. One of these, the zinc barium silicate, is a true "red" phosphor, similar to cadmium borate in that no appreciable variations in its emission spectrum can be obtained; the other resembles the alkaline earth halophosphates in being "double activated," the fluorescent color being modifiable by variation in the amount of the second activator.

ZINC BARIUM SILICATE PHOSPHOR

When trying to substitute other metals for beryllium in zinc beryllium silicate phosphor it was noticed that barium was having a slight, but definite, modifying effect on the phosphor's emission spectrum.

Experimentation eventually showed that introduction of barium along with the components of zinc silicate:Mn phosphor could produce a compound giving a deep red fluorescence. However, unlike zinc beryllium silicate in which BeO can be varied continuously over a wide range producing a proportionate color change in fluorescence, there is only one zinc barium silicate:Mn that is effective as a phosphor. In this, the ratio is 1 mol BaO to 2 mols ZnO. If more or less ZnO is used, two phases always seem to develop. With excess ZnO, the red fluorescent material is accompanied by ordinary green fluorescent zinc silicate:Mn. With excess BaO, the red fluorescent compound is accompanied by a non-fluorescent barium silicate which is usually discolored by manganese. In either case, more than a slight excess leads easily to almost complete obliteration of the red fluorescence, and in the case of excess barium, the compound is more readily fused. Ordinary AR quality ZnO and $BaCO_3$ chemicals only have, so far, been used in this work.

The amount of silica that may be used in the production of the phosphor is not critical. With the type of silica actually used, which was a highly reactive one, the material can be represented as $BaO \cdot 2ZnO \cdot xSiO_2$ where x may lie between 1.7 and 7, and is preferably about 2.

We have found it best to fire at as high a temperature as possible, con-

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sistent with the production of a material that is not fused or sintered too hard for practical use.

For a 50 g. sample, the firing should be of the order of one hour at 1050°C. followed, after an intermediate grinding, by another hour at 1100°C. A third firing for an hour at 1100°C. is sometimes advantageous.

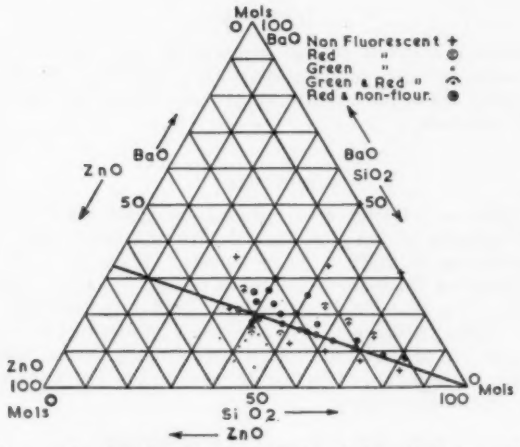

FIG. 1. Diagram showing the effect of variation of the ratio between BaO:ZnO:SiO_2 on zinc-barium-silicate phosphor.

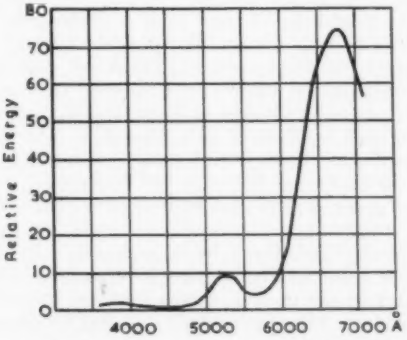

FIG. 2. Spectral distribution curve for zinc-barium-silicate phosphor.

A plot on the triangular diagram of Fig. 1 shows variation of fluorescent color with composition. It will be seen that the compositions giving red fluorescence lie on, or very close to, the line for $BaO \cdot 2ZnO$.

The amount of manganese activator is not critical and can be used at half or double the preferred amount without very appreciable effect. The

amount generally used was 5 per cent (of $MnCl_2 \cdot 4H_2O$) calculated on the basis of the mixed oxides.

We prefer to introduce the manganese as chloride in order to get the best results. So far, no other activators have been found satisfactory.

Fluorescent lamps have been prepared from this phosphor. They have a pinkish purple appearance and, as may be expected from the emission curves, give very prominent color rendering of reds. An energy curve of the phosphor emission in an 80 watt fluorescent lamp is shown in Fig. 2.

As might be expected from such long wave fluorescence, the lumen output of the lamps is low. Representative results are: 8.4 lumens/watt at ½ hour, and 7.0 lumens/watt at 100 hours.

Fig. 2 shows a small hump at about 3700 Å, another larger one at 5200–5300 Å, and a peak at approximately 6750 Å. The first may be due to barium silicate or zinc barium silicate activated by an unknown activator. The second corresponds to the emission of ordinary Zn_2SiO_4:Mn. It is interesting to compare the peak of the curve at 6750 Å with that of $Ca_3(PO_4)_2$:Ce, Mn (at 6550 Å) and that of cadmium borate (at 6200 Å). At 7000 Å, the relative proportions of the peak emission intensity are approximately 85 per cent, 55 per cent, and 10 per cent, respectively.

ALUMINUM PHOSPHATE PHOSPHOR

Following a considerable amount of work on alkaline earth halophosphate phosphors and similar compounds, a series of aluminum phosphate phosphors was developed which are responsive to 2537 Å radiation.

We are aware that aluminum phosphate activated by tin and manganese has been mentioned in a publication (British Patent 512,154), but there does not seem to have been published any information regarding the shape of the spectral emission curves, or their variations as a function of the manganese content.

These phosphors are of the double activator type, the primary activator being tin and the secondary activator manganese. When activated with tin only, the phosphor shows a bluish-greenish-white fluorescence under a low pressure Hg quartz lamp. (The visible radiation from the exciting lamp was filtered out with a 3 mm. sheet of Corning No. 9863 M6138 glass.)

Addition of manganese produces an increase in emission at the red end of the spectrum at the expense of the blue end. The emission of most of these phosphors falls roughly into the general classification of "white emitting phosphors," although the emission of the reddest one is comparatively saturated. Unlike most other well known single "white" phosphors such as the alkaline earth halophosphates, or two powder "white" mixtures, the spectral energy curves are fairly smooth and free from secondary peaks. Spectral energy emission curves for three phosphors with different amounts of manganese are shown in Fig. 3.

Powder E 350 with the highest emission in the red (peak at 6400 Å) contains 7 per cent $MnCl_2 \cdot 4H_2O$ as an addition to the mixture before firing. Other phosphors containing more manganese are possible and give more emission at the red end of the spectrum. The other curves shown (powders E 349 and E 348) were obtained from powders containing progressively less manganese (3.5% and 1.4% $MnCl_2 \cdot 4H_2O$, respectively).

The only satisfactory method of preparation that we have found so far is to heat together a dry mixture of aluminum oxide or hydroxide, diammonium hydrogen phosphate, stannous chloride, and, when required, manganese chloride.

The amount of tin required is not critical and can be varied by a factor of 2 each way from the amount usually used. This was 3.5 per cent $SnCl_2 \cdot 2H_2O$ calculated on the mixture of the two major constituents before firing.

Most of the work was carried out with mixtures of diammonium phosphate and aluminum hydroxide containing one mol of each, i.e., corresponding to the formation of $AlPO_4$. Addition of 50 per cent excess of the aluminum hydroxide tends to produce very great losses in fluorescent brightness. A similar excess of the phosphate has little effect, much of it probably being lost by volatilization.

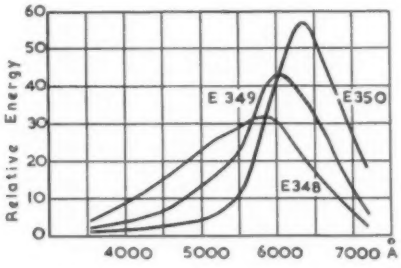

FIG. 3. Spectral distribution curve for aluminum phosphate phosphors with varying manganese content.

The mixture is fired in air, in quartz containers, at temperatures ranging from 850° to 1250°C. In our experience, the highest temperatures give the best results, and probably the higher temperatures still could be used to advantage.

During firing, the mass in the crucible bubbles and becomes plastic. On cooling, an aerated opaque semiglass is obtained. This can be powdered fairly readily to make it usable for lamp coatings. Attempts to obtain the sintered powder state, in which normal phosphors are usually prepared, have resulted in materials having poor fluorescent properties. It seems possible that the vitreous state is necessary for the full development of fluorescence.

Although the phosphors can be applied to lamp tubes in the usual nitrocellulose suspension, difficulty is experienced in completely baking out the latter and its decomposition products. This probably accounts for the fact that many lamps either showed early failure (around 500 hours) or blackened excessively.

Luminous efficiencies of 80 watt fluorescent lamps are shown below. The latter were coated with the phosphors shown in Fig. 3.

Lamp designation	Average efficiency in lumens/watt at	
	0 hr.	100 hr.
E 348	25-26	23-24
E 349	20	18-20
E 350	11-11.5	8-10.5

Limitations in time have so far precluded a more extensive study of these materials including an examination of their crystal structure. The aluminum phosphates do not respond well to excitation by cathode rays, but the zinc barium silicate responds well, giving a fluorescence slightly redder than that given by $MgSiO_3$:Mn.

Any discussion of this paper will appear in the discussion section of Volume 95 of the TRANSACTIONS of the Society.

THE CONSTITUTION OF ZINC BERYLLIUM SILICATE PHOSPHORS AND ITS EFFECT ON THEIR LUMINOUS PROPERTIES[1]

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ABSTRACT

The constitution of zinc beryllium silicates, prepared at temperatures in the neighborhood of the normal firing temperature, has been investigated. The limit of solubility of beryllium in zinc silicate at 1260°C. was found to be at about 25 molar per cent for phosphors containing 2.5 per cent manganese, as well as for unactivated products. This is only slightly below the value of 30 molar per cent found previously at the fusion temperature. No evidence could be found of a further reduction in solubility at temperatures below 1260°C. At 1260°C. the reaction between beryllia and silica alone is so slow that no appreciable amount of beryllium silicate could be detected until zinc oxide was added in addition, denoting that zinc silicate serves as a flux to catalyze the beryllia reaction. Firing at 1180° was incapable of dissolving all the beryllia present, even for compositions below the saturation point.

Maintenance of phosphors in lamps was somewhat better for a composition slightly higher in beryllia than corresponded to the saturation point. The maintenance was still better for phosphors prepared at 1180°C., a temperature at which not all of the beryllia introduced could be dissolved.

The initial rate of decay of phosphorescence is exponential. The rate becomes greater as the concentration of either beryllium or manganese is increased. For a phosphor of standard color, the decay rate is smaller if this color is attained by the use of high beryllia and low manganese rather than the reverse.

INTRODUCTION

When zinc and beryllium oxides are fired with silica at sufficiently high temperatures, a solution of the two silicates is formed. There is, however, a limit to the solubility of beryllium silicate in zinc silicate, and its effect in altering the fluorescence color of phosphors is limited to the solubility range (1). When the amount of beryllium introduced is in excess of this range, separate phases are formed.

The previous measurements of solubility were made on phosphors prepared by fusion at about 1550°C. A redetermination has now been made with the aim of finding the extent to which the solubility limit is altered when the phosphor mixture is fired below fusion at temperatures used in normal preparation. More detailed consideration has also been given to the nature of the products formed outside of the solubility range and to features of abnormal color emission. Finally, the effect of constitution has been investigated on lumen maintenance in fluorescent lamps and on phosphorescence decay.

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As material for the investigation, Dr. H. C. Froelich of the General Electric Company at Nela Park prepared silica mixtures with variable content of zinc and beryllium oxides and fired them for 2 hours, one series at 1260°C. and a second series at 1180°C. The composition of the mixtures was maintained at the proportion of one mol of silica to two mols of the combined metallic oxides.

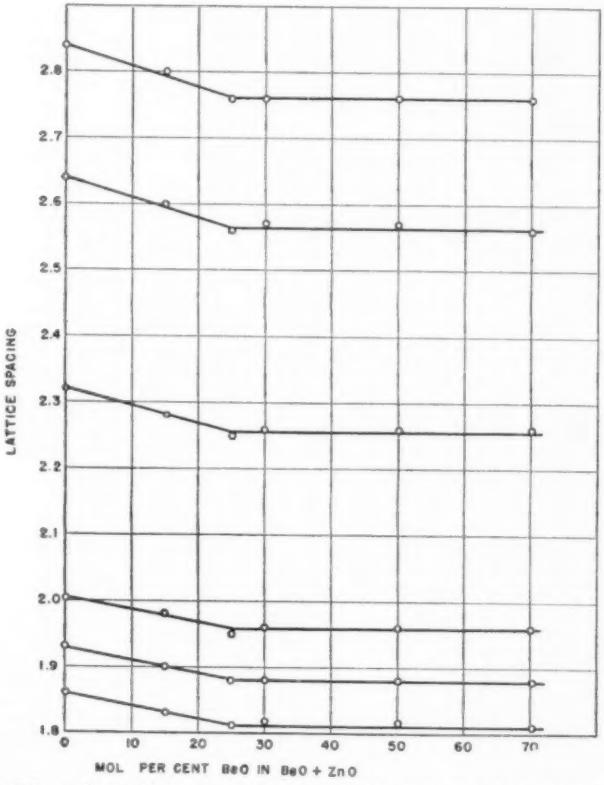

FIG. 1. Effect of beryllium concentration on lattice spacing of zinc beryllium silicate solid solutions.

CONSTITUTION

For a general survey of the situation, diffraction patterns were measured of unactivated samples which had been prepared at 1260°C. These patterns were recorded by Mr. Eric Asp of this laboratory with Cu K_α radiation from the North American Philips Geiger counter x-ray spectrometer. The strongest lines of the patterns are given in Table I for seven samples ranging in composition from 0 to 90 molar per cent beryllia with reference to the combined content of zinc and beryllium oxides. The relative in-

tensity of each line is recorded under the heading "I." To facilitate comparison of the various samples, the intensity of the strongest line in the pattern of the solutions is expressed as 100. In the pattern of the pure orthosilicate, Zn_2SiO_4, this line corresponds to the spacing of 2.64 Å. Fig. 1 shows graphically the changes in lattice spacing with composition for six typical lines.

TABLE I. *Diffraction patterns of products formed at 1260°C. by firing mixtures of zinc and beryllium oxides with silica*

308 No BeO		310 15% BeO		312 25% BeO		303B 30% BeO		313 50% BeO		314 70% BeO		315 90% BeO		Product responsible for line
d	I	d	I	d	I	d	I	d	I	d	I	d	I	
7.00	10	6.85	16	6.60	23	6.80	23	6.80	25	6.80	31	6.80	61	ZBS
										4.10	25	4.08	160	SiO_2
4.03	29	3.99	32	3.88	33	3.91	34	3.95	40	3.90	44			ZBS
										3.70	14	3.67	115	Unknown
		3.41	84	3.39	79	3.40	97	3.40	85	3.40	100	3.38	200	ZBS plus unknown
3.29	5	3.22	5	3.14	8	3.19	12	3.19	10	3.19	11			ZBS
3.14	6	3.10	5	3.04	5	3.09	9			3.09	11	3.11	54	ZBS plus Be_2SiO_4
2.84	88	2.80	91	2.76	95	2.76	104	2.76	104	2.76	89	2.76	100	ZBS
2.64	100	2.59	100	2.56	100	2.57	100	2.57	100	2.56	100	2.57	100	ZBS
												2.49	69	Be_2SiO_4
						2.35	3	2.35	12	2.34	20	2.33	103	Be_2SiO_4 plus BeO
2.32	50	2.28	51	2.25	54	2.26	51	2.26	49	2.26	45	2.26	69	ZBS
2.21	4	2.20	2			2.17	3	2.18	11	2.19	11	2.18	69	ZBS plus Be_2SiO_4
2.14	7	2.11	8	2.08	3			2.08	4	2.06	28	2.06	123	ZBS plus Be_2SiO_4
2.02	10	1.98	15	1.95	10	1.96	9	1.96	5	1.96	15	1.97	23	ZBS
												1.903	34	Be_2SiO_4
1.93	12	1.90	12	1.88	15	1.88	15	1.88	13	1.88	11			ZBS
1.860	42	1.830	40	1.810	42	1.815	43	1.815	36	1.810	33	1.820	61	ZBS
												1.730	28	Be_2SiO_4 plus BeO
												1.698	23	BeO
1.690	8	1.670	8	1.640	10	1.645	12	1.645	12	1.640	11			ZBS
1.640	8	1.620	8	1.600	8	1.600	7	1.600	8	1.600	15	1.600	23	ZBS
1.600	13	1.580	13	1.560	13	1.560	11	1.560	15	1.560	12			ZBS
1.555	12	1.530	13	1.520	13	1.518	11	1.516	12	1.512	8			ZBS
1.520	10	1.500	8	1.480	9	1.482	12	1.485	7	1.480	7			ZBS
												1.420	15	Be_2SiO_4
1.420	36	1.400	44	1.390	36	1.389	37	1.389	29	1.385	31	1.390	31	ZBS
1.390	5	1.375	6	1.360	4	1.360	5	1.350	4	1.350	6	1.349	31	ZBS plus BeO
1.368	18	1.349	15	1.333	18	1.331	15	1.332	12	1.330	15	1.335	15	ZBS
1.340	18	1.320	15	1.309	14	1.305	17	1.305	15	1.302	14	1.309	18	ZBS
												1.260	23	Be_2SiO_4
1.250	3	1.235	3	1.230	4					1.230	8	1.240	34	ZBS plus BeO

When beryllium silicate is dissolved in zinc silicate, the lattice is unaltered except for the substitution of beryllium ions for an equivalent number of zinc ions. Inasmuch as the beryllium ion is much smaller than the zinc, there is a contraction of the lattice which continues uniformly up to the limit of solubility. The curves demonstrate that this point is reached at 25 molar per cent BeO. Beyond this concentration, the lattice dimensions remain constant. The conclusion from these survey tests is, therefore, that 25 molar per cent represents the limit of solubility of Be_2SiO_4 in Zn_2SiO_4. The question remains, what happens to the rest of the beryllia?

The answer is found in the enhanced intensity of certain lines and in the appearance of new lines, changes that are first manifest in Table I for phosphor 303B, containing 30 molar per cent BeO. As the amount of BeO is increased beyond this point, the relative intensity of these lines becomes continuously greater, reaching a maximum at 90 molar per cent. As recorded in the last column of the table, these lines denote the presence of Be_2SiO_4, free BeO, and free SiO_2 in the form of α-cristobalite. The symbol ZBS in this column is an abbreviation for zinc beryllium silicate.

It is evident therefore that only part of the undissolved beryllia reacted with the silica to form Be_2SiO_4. In fact, the formation of Be_2SiO_4 at 1260°C. depended upon the presence of Zn_2SiO_4 as a "flux." In sample 296, prepared from a mixture of $2BeO + SiO_2$ with no zinc oxide, the pattern was identical with that from a similar mixture in which the ingredients had been fired separately and then mixed. This proved that no

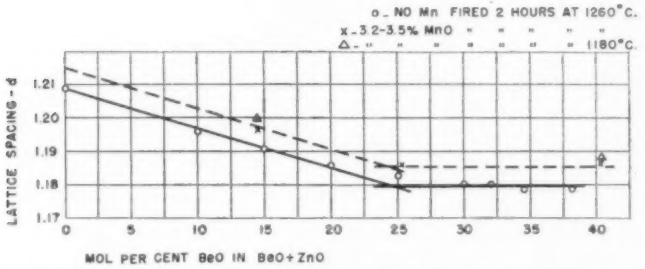

FIG. 2. Lattice spacings for innermost line in back-reflection diffraction patterns of zinc beryllium silicates.

Be_2SiO_4, or only an insignificant amount, had been formed in 296. This is further evidence that the reaction between beryllia and silica is so reluctant that it is the controlling factor in the formation of completely reacted phosphors.

In order to obtain greater accuracy in measurement of the solubility limit, the measurements were repeated and extended photographically by Mrs. Beulah F. Decker, using Cu-Kα radiation and a spectrometer capable of recording back reflections of lines. To get the highest sensitivity, the extent of contraction of the lattice was found by calculating the lattice spacing for the innermost line, that which had been most nearly reflected to 180°.

The *d*-values corresponding to the position of this line are recorded in Table II for two series of phosphors. Mrs. Decker reports that they are accurate to the third decimal place. The first series contains manganese, the second is without manganese. The results for phosphors prepared at 1260°C. are shown graphically in the curves of Fig. 2. Again, the contraction in the lattice continues uniformly to a concentration of 24–25 molar per cent BeO. The curve for phosphors containing manganese shows the same solubility limit but lies parallel at a higher level. This denotes a uniformly larger lattice size, which is due to the larger ionic radius of manganese. Manganese has an extensive solubility in zinc silicate.

Reference to Table II shows that the lattice spacing of phosphors fired at 1180°C. is slightly higher than found at 1260°C. The difference, even though small, is to be ascribed to an incomplete reaction. The results indicate that the solubility limit is the same as at 1260°C.

This conclusion was strengthened by subjecting samples fired at 1260°C. to a refiring at lower temperatures. This is particularly significant for those samples containing more than 25 molar per cent BeO—the range in which the constancy of lattice spacing denoted attainment of a saturated solution at 1260°C. Within this range, any decrease in solubility would be

TABLE II. *Lattice spacings of zinc beryllium silicates of variable composition*

No.	Mol % BeO	% by wt. Mn	Firing temp.	Refiring temp.	G/R	d-value
297A	14.5	2.7	1260°	—	0.97	1.1961
297A	14.5	2.7	1260°	1260°	0.96	1.1951
298A	25.4	2.5	1260°	—	0.57	1.1853
299A	40.4	2.2	1260°	—	0.62	1.1864
299A	40.4	2.2	1260°	1260°	0.63	1.1880
302A	40.4	2.2	1260°	—	0.57	1.1854
297C	14.5	2.7	1180°	—	1.53	1.1997
297C	14.5	2.7	1180°	1180°	1.24	1.2003
299C	40.4	2.2	1180°	—	0.69	1.1883
302C	40.4	2.2	1180°	—	0.59	1.1889
308	nil	nil	1260°	—		1.2089
309	10.0	nil	1260°	—		1.1960
309	10.0	nil	1260°	1100°		1.1949
310	15.0	nil	1260°	—		1.1905
311	20.0	nil	1260°	—		1.1856
312	25.0	nil	1260°	—		1.1826
312	25.0	nil	1260°	1030°		1.1836
312	25.0	nil	1260°	900°		1.1827
303B	30.0	nil	1260°	—		1.1800
303B	30.0	nil	1260°	1100°		1.1802
303B	30.0	nil	1260°	1030°		1.1827
303B	30.0	nil	1260°	900°		1.1807
305	32.0	nil	1260°	—		1.1800
306B	34.0	nil	1260°	—		1.1781
307	38.2	nil	1260°	—		1.1786
313	50.0	nil	1260°	—		1.1771
313	50.0	nil	1260°	1100°		1.1797
314	70.0	nil	1260°	—		1.1771

denoted by an increase in lattice spacing. An increase in solubility would be shown by a decrease in spacing. Various samples of the unactivated mixtures were refired for 2 hours at 1100°C., 14 hours at 1030°C., and 33 hours at 900°C. In no case did a significant change occur.

A consideration of these data with those obtained by the author previously (1) leads to the conclusion that there is a slight reduction in solubility at 1260°C. The 30 per cent limit found at the fusion temperature of about 1500°C. falls to 25 per cent at 1260°C. Whatever further reduction occurs at still lower temperatures appears to be too small for conclusive detection. Kroeger (2) has reported that at 1150°C. the solubility limit is as low as 12 per cent Be_2SiO_4. Because of the sluggishness of the reactions involved, it may be that his results simulated the attainment of

saturation at a concentration that was too low. The change in solubility from 30 per cent at 1500°C. to 25 per cent at 1260° C. appears reasonable. At still lower temperatures, the rates of reaction and of diffusion become very slow, so that they render difficult the measurement of the further reduction which is to be expected.

MAINTENANCE IN LAMPS

The phosphors prepared by Dr. Froelich for this investigation afforded an opportunity to find if there were any characteristic differences in maintenance that resulted from changes in constitution. Life tests have previously been reported on standard forms of the phosphor by Meister and Nagy (3), and by Lowry (4). The latter has demonstrated the variations in maintenance that are encountered in practice and has subjected his results to analysis in an attempt to elucidate some of the causes for these variations. The present data are presented to draw attention to additional factors that may be present.

The phosphors were mounted as disks in tubular types of the low pressure mercury discharge. The disks were obtained by pressing the dry powder, without binder, into circular recesses, in a long glass slab. The recesses were 1 cm. in diameter and 1 mm. deep. Five disks of different phosphors were mounted, about 5 cm. apart, on one slab. This slab was fastened within a 1 inch (2.54 cm.) tube such as is used in the 15 watt fluorescent lamp and standard cathodes were sealed in. Results on the five different phosphors are therefore comparable, independent of chance variations in the character of the discharge. After exhaust for 1 hour at 380°C., followed by introduction of argon and mercury and by activation of the cathodes that was sufficiently prolonged to remove troublesome impurities, the tube was mounted in a rigid position and operated at constant current. The brightness of each disk was measured with a light sensitive cell mounted at one end of a cylinder. A lens served to focus a diffuse image of a disk over the surface of the cell. This device was held at a fixed distance from the lamp containing the disks and was moved in a direction parallel to the lamp. The brightness of each disk was always measured at the position giving maximum intensity. Readings were reproducible to within 0.2 per cent.

Two agents responsible for abnormal depreciation had to be carefully avoided, alkali and moisture. When potassium silicate was used as a binder, a 30–50 per cent decrease in brightness occurred within 60 hours of operation. It was for this reason that phosphors were used in the final tubes as dry powders. A further precaution was found necessary, that the tubes be exhausted immediately after fabrication. When a tube was left unexhausted for three days in moist air, the phosphors lost 25–35 per cent in brightness in 60 hours.

When tubes were made with these precautions in mind, reproducible results were obtained. There was, it is true, some variation in absolute values from one tube to another but the relations between the maintenance of different phosphors, as tested in individual tubes, remained the same on repeated tests. To demonstrate that the results agree with large scale factory tests of lamps, a test was made of two phosphors, one of which, A, had shown consistently good lumen maintenance and the other, B, poor lumen maintenance. They were tested with one of Dr. Froelich's

phosphors, 297C, which showed superior maintenance. The results, as given in Fig. 3, are in accord with the factory reports. Phosphors A and B were both of the standard composition as used in 3500° white lamps. The lattice spacing for A however was slightly lower than for B, 1.1969 vs. 1.1980, in terms of the *d*-value quoted previously in Table II. It may be only a coincidence, but the same relation between maintenance and lattice size was shown for a pair of the Froelich phosphors, 297A and C, which had been fired at 1260°C. and 1180°C., respectively.

The relative maintenance of these phosphors brings out a typical difference between products prepared at these two temperatures. Repeated tests showed no consistent difference in performance between phosphors prepared at the same temperature from mixtures containing 14.5 molar per

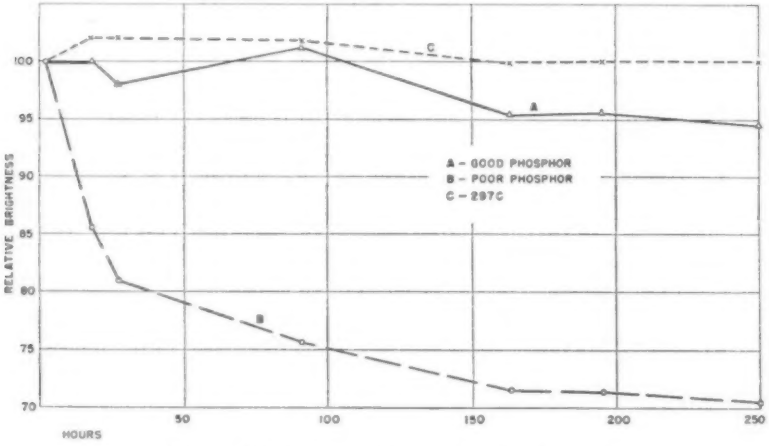

FIG. 3. Maintenance of good and poor phosphors

cent BeO and those with 40.4 molar per cent. There was, however, a uniformly better maintenance for the series prepared at 1180°C. than for that prepared at 1260°C. This difference persisted even in a tube which had been exposed to moist air for the purpose of aggravating the depreciation.

The difference is demonstrated for well-exhausted tubes by the maintenance measurements which are recorded in the curves of Fig. 4 and 5. In each case the test was repeated and the measurements found to be in close agreement. The points in the curves are the averages of measurements from the two tubes. To avoid confusion, the tests are limited to two phosphors, 297A and C, prepared from mixtures containing 14.5 molar per cent BeO. A similar relationship was found for 299A and C, from mixtures with 40.4 molar per cent.

From Table II it is apparent that refiring 297A at 1260°C. gave no further change either in its spectral distribution or in its lattice dimensions, a demonstration that it is in a stable, completely reacted form. Refiring

297C at 1180° shifted the fluorescence toward the red but, strange to say, had no effect upon the lattice. It is probable, however, that 297C represents an incompletely reacted phosphor.

A satisfactory explanation for the better performance of the 1180° product is not yet at hand. The presence of unreacted BeO or Be_2SiO_4 is, no doubt, one factor. This was confirmed by a comparative test between 297A and 298A. Both were prepared at 1260°C. but the composi-

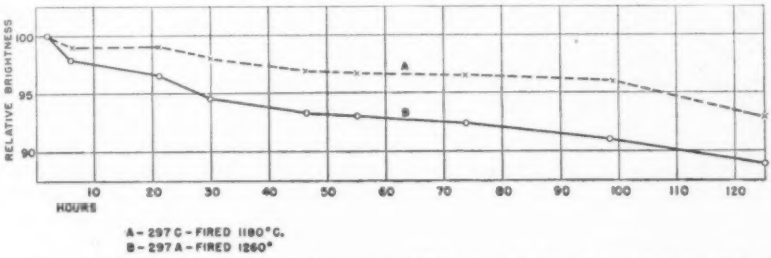

FIG. 4. Maintenance of phosphors over 100 hour period as dependent on firing temperature.

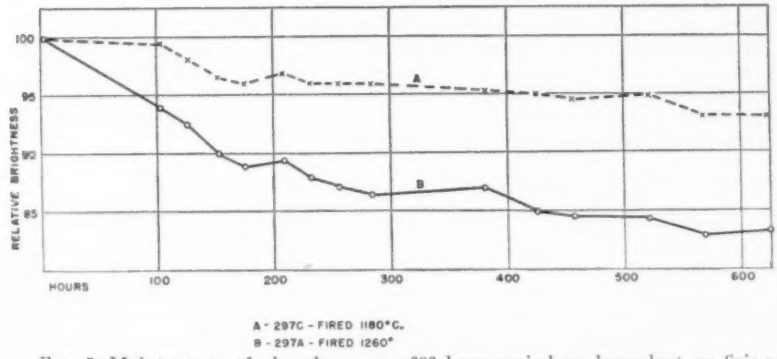

FIG. 5. Maintenance of phosphors over 600 hour period as dependent on firing temperature.

tion of the latter, 25.4 molar per cent BeO, was so close to the saturation point of the solid solution, that it would be expected to contain some undissolved beryllium. It did in fact show a consistently better maintenance but the difference was not as great as was found for 297A and C. It appears therefore that a further factor is involved, a factor that is related to the lower temperature of formation.

In conclusion, it is of course generally accepted that rapid depreciation occurs after exposure to moisture. There is as yet no general agreement as to the seriousness of photolysis. Meister and Nagy (3) have presented evidence to show that photolysis is negligible under 2537 Å but that it is

sufficiently active under 1850 Å to account for the pronounced depreciation which occurs. The present tests show such good maintenance for the phosphors of curves A and C in Fig. 3, 4, and 5, that it is hard to accept photolysis, even if present, as an inherently active agent in depreciation.

This conclusion was strengthened by two further tests in which phosphor disks, prepared as described above, were mounted in evacuated quartz tubes and were then tested under radiation external to the tubes. In order to avoid errors due to variation in the intensity of exciting radiation, depreciation was measured relative to a blank phosphor disk which was not life tested. Four phosphors were tested under a germicidal lamp, emitting 2537 Å radiation only. Two of them had given good performance in lamps tested at Nela Park and two had shown bad maintenance. Measurements made at intervals over a period of 211 hours showed no depreciation for any phosphor, in agreement with the results of Meister and Nagy.

In the second test, two of these phosphors were tested under radiation from a low pressure mercury discharge in a quartz tube, emitting 1850 Å as well as 2537 Å. Measurements were made at intervals over a period of 100 hours. The phosphor which had shown bad depreciation in lamp life tests showed no variation whatever in light output. The other phosphor, characterized by good life in lamps, fell 6 per cent in brightness by the end of 100 hours. This result is somewhat ambiguous but again it denotes that photolysis under 1850 Å is not inherently an active factor.

The conclusion from these various tests is, therefore, that the cause of early depreciation is to be found, not in photolysis, but rather in the adsorption of excited mercury atoms on the surface of the phosphor grains, as discussed by Froelich (5). Variations in the extent of depreciation shown by different phosphors would thereby denote that there is a characteristic surface structure or constitution, present in some phosphors, which is favorable to this type of reaction.

DECAY RATE OF PHOSPHORESCENCE

The characteristics of the decay during the first 35 milliseconds were measured for several groups of phosphors, including the Froelich samples whose constitution and maintenance have been described in the two previous sections. For the sake of conciseness, the data given below are confined to the group of phosphors prepared by fusion. They cover amply the significant range of composition and the results from them are in accord with results from phosphors prepared at normal firing temperatures.

The same phosphoroscope was used as in an earlier investigation (6). A sector having a 90° opening was placed between the phosphor screen and the source of 2537 Å. This afforded a sufficiently long time of excitation to bring the intensity of fluorescence to an equilibrium value.

For the first 10–15 milliseconds, the decay was exponential, in accordance with the equation,

$$P = P_0 e^{-kt}$$

where P_0 is the initial intensity and P the intensity at time, t. Thereafter the rate of decay became slower and tended toward the bimolecular stage typical of the trapped type of phosphorescence. This second stage of decay is temperature sensitive. With the zinc beryllium silicate phos-

phors it is not sufficiently extensive to be an important characteristic, as with the sulfides, nor is it of sufficient magnitude to affect the initial rate. It is, therefore, the temperature-insensitive, exponential decay which is the predominant feature in their phosphorescence. It is this type of decay which determines the extensiveness of flicker from a phosphor in a lamp under AC operation.

TABLE III. *Effect of composition on decay rate and color of zinc beryllium silicate phosphors*

Lot No.	Molar per cent BeO	Wt. per cent Mn	Relative intensity Emission bands		Decay rate
			Green	Red	
—	0	0.5	100	0	80 sec.$^{-1}$
519	7	1.0	92	8	97
526	7	2.5	69	31	142
527	7	4.0	75	25	193
520	15	1.0	69	31	108
528	15	2.5	25	75	156
529	15	4.0	0	100	193
521	30	1.0	38	62	120
530	30	2.5	0	100	170
531	30	4.0	0	100	193

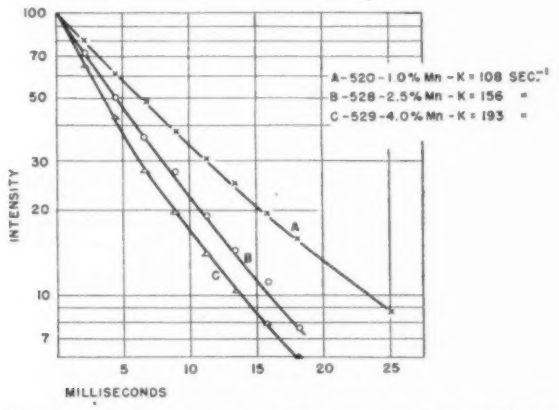

FIG. 6. Effect of manganese content on decay rate of zinc beryllium silicate containing 15 molar per cent BeO.

A typical set of decay curves is given in Fig. 6. A summary of the results over the range investigated is given in Table III. The relative intensity of the emission bands is not, in this case, a measure of the relative transmission of fluorescence through green and red filters, but is derived from spectral distribution curves taken by Dr. F. J. Studer, some of which are in addition to his published data (7). To obtain the values given in the table, a somewhat arbitrary attempt was made to define the magnitude

of each band. The ratio of their peak intensities was then taken as a measure of their relative intensities.

It is important to observe that the exponential decay appears to be homogeneous. It is not a composite of two separate decay processes, one for the green band and a second one for the red band, each characterized by a different rate. Furthermore, the eye can perceive no change in color

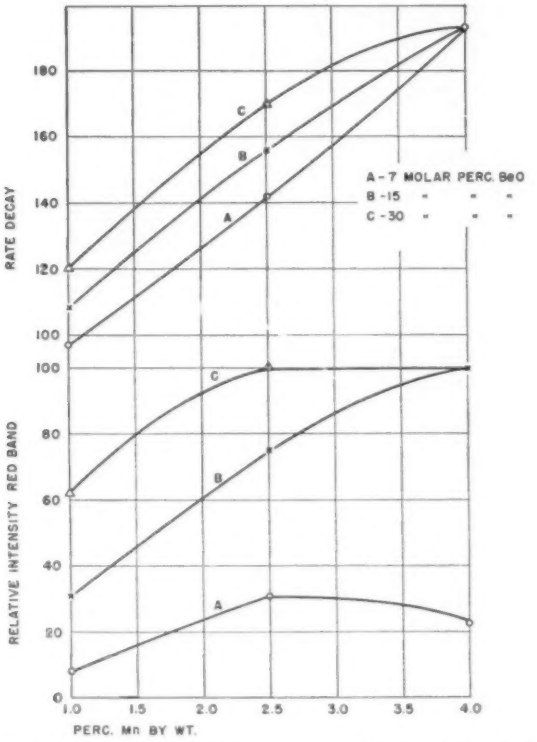

FIG. 7. Relation between rate of decay, color, and composition of zinc beryllium ilicate phosphors.

during decay such as would necessarily be the result if two processes at different rates were involved (8).

A graphic summary is given in Fig. 7 to show the dependence of decay rate and color upon composition. As the decay rate becomes lower, the flicker of the phosphor in lamps is reduced. It is therefore desirable from this viewpoint, to choose phosphors for lamps having a minimum decay rate. The zinc beryllium silicates have higher rates than zinc silicate devoid of beryllium. Unfortunately, such appreciable amounts of beryllium and manganese must be used to obtain the amount of red desired

that the rate becomes considerably higher. From Fig. 7, it is apparent that a lower rate of decay for phosphors of standard emission color is obtainable by using high beryllium content and low manganese rather than low beryllium and high manganese. There are, of course, other important considerations which make necessary the choice of the latter combination.

Any discussion of this paper will appear in the discussion section of Volume 95 of the TRANSACTIONS of the Society.

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PREPARATION AND PROPERTIES OF SILICON MONOXIDE[1]

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ABSTRACT

A friable, massive, black, resinous material satisfying the chemical formula for silicon monoxide has been made by the controlled condensation of vapors obtained by heating silicon and silica in a vacuum. The material is completely soluble in hydrofluoric acid, is an electric insulator, and is structurally different from either silicon or silica, as revealed by x-ray and electron diffraction studies.

REVIEW OF PREVIOUS WORK

The partial reduction of silica was first investigated by Potter in 1907 (1), who prepared "Monox" by heating a suitable mixture of silica and carbon in a vacuum arc furnace. The product was an extremely fine, silky-feeling, light brown, opaque powder which later x-ray diffraction studies in 1941 by H. N. Bauman, Jr., (2) proved to be a finely divided mixture of silicon and cristobalite.

In 1928, Bonhoeffer (3) published data on absorption spectra showing the formation of silicon monoxide.

Later in 1941, Zintl (4, 5, 6, 7) studied volatilization in vacuo from mixtures of silicides and silicates and reported obtaining a brownish-black, glassy condensate and brown, shellac-like skins by slow condensation, whereas, previously, silicon monoxide was usually made as a very fine, brownish powder. X-ray diffraction patterns of these products indicated the presence of silicon.

In 1942, Zapffe and Sims (8) published an extensive review of the literature on silicon monoxide and its bearing on steel practice.

Notwithstanding the work already done, confusion still existed concerning the chemical identity of so-called silicon monoxide. Its volatilization at lower temperatures than those required for silicon and silica was ascribed by some to the existence of a lower boiling azeotrope of silicon and silica.

EXPERIMENTAL PROCEDURE

Initially, the experiments performed at the Union Carbide and Carbon Research Laboratories, Inc., paralleled those of Zintl and his associates. The experiments centered about the following types of reactions:

$$\mathrm{MeO} + \mathrm{Si} = \mathrm{Me} + \mathrm{SiO}\ \text{(vapor)}$$

$$x\mathrm{MeO}\cdot y\mathrm{SiO_2} + y\mathrm{Si} = x\mathrm{MeO} + 2y\mathrm{SiO}\ \text{(vapor)}$$

The condensates obtained at first were brown and apparently consisted of a very finely divided mixture of silicon and silica due to the following reverse reaction:

$$2\mathrm{SiO} = \mathrm{SiO_2} + \mathrm{Si}$$

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In succeeding experiments, this reaction was investigated further. When the brown condensate was leached with hydrofluoric acid, the silica portion, approximately 68 per cent, dissolved leaving finely divided silicon. By increasing the rate of quenching of the silicon monoxide vapor generated by heating a mixture of silicon and silica, more than 68 per cent became soluble in hydrofluoric acid. The products thus obtained corresponded to those described by Zintl and his associates.

Finally, by closer control of vacuum, temperature, and rate of condensation, a product was obtained, with an analysis corresponding to SiO, that was completely soluble in hydrofluoric acid.

Silicon monoxide, made in this way, was a black, resinous-looking material unlike the brown decomposed product. On reheating to between 1300° and 1375°C. under an inert atmosphere, this black product became decomposed to a tan-colored material which was soluble in hydrofluoric acid only to the extent of 68 per cent. By leaching out the silica in this manner, a product containing 99.9 per cent silicon has been obtained. A similar product was obtained by reacting silica and carbon, but it contained some silicon carbide presumably due to a reverse reaction:

$$3SiO + CO = SiC + 2SiO_2$$

PROPERTIES OF SILICON MONOXIDE

The black SiO condensate resulting from the reaction of silicon and silica under suitable conditions is completely soluble in hydrofluoric acid. Its density is about 2.2. Whereas the more readily obtained brown SiO condensate is an electrical conductor with high resistance, the black resinous-looking material is almost non-conducting. Measurements made on a $\frac{3}{16}$-inch thick disk of 1-inch diameter gave the dielectric values shown in Table I. The electrical properties of thin films of silicon monoxide were not determined.

TABLE I

Frequency in megacycles	Power factor	Dielectric constant
0.05	0.011	5.0
1.5	0.004	4.9
10.0	0.004	4.8
70.0	0.003	4.8

The black SiO condensate gives no x-ray diffraction pattern, but the more readily obtained brown condensate or the annealed black product gives the typical silicon pattern. For comparison, electron diffraction patterns were obtained from metallurgically refined silicon, chemically purified silicon, brown SiO, black SiO annealed in argon at 1375°C., black SiO, and the silica flour used in making SiO. The first four gave patterns which checked the silicon x-ray pattern. The lines for the first two were spotty, indicating large crystallite sizes. For the next two, the lines were smooth and diffuse, indicating finely divided silicon. The silica flour gave a quartz pattern, but the black SiO showed three noticeable halos or bands after long exposure, corresponding to spacings of approximately

3.6, 1.8, and 1.2 Å. The band spacing corresponding to 3.6 Å was reasonably clear, and this value is almost exactly midway between that of the strong line of silicon at 3.12 Å and that of cristobalite at 4.04 Å. The broadness of the halos indicates either amorphous character or ultimate particle sizes on the order of 10 to 15 Å.

Silicon monoxide is presently used for coating first surface mirrors and optical glass by condensing a film of the material on these surfaces in vacuo to serve as a protection against abrasion and tarnishing.

CONCLUSION

It is concluded that black SiO is a nearly amorphous, polymeric material with the composition SiO.

ACKNOWLEDGMENT

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AN ANOMALOUS LUMINESCENT EFFECT[1]

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ABSTRACT

The luminescence caused by the radiations emitted from radon, when confined over a plane surface of phosphorescent zinc sulfide, is not uniform. Bright and dark areas occur in a variety of unpredictable configurations and these areas slowly change their form and light intensity with time. Although some of the changes in luminosity are apparently affected by magnetic field, the real cause of the effect has yet to be found. The luminosity is sufficient to produce photographs through short time exposures without film fogging. Such photographs serve as records of the effect.

The production and utilization of radioactive luminous materials stems from the early discovery that certain natural and synthetic compounds become luminous in the presence of radium bearing substances. Of the various materials manifesting this phenomenon, zinc sulfide phosphors were found to give the highest luminosity per unit quantity of radium. It was also found that practically all of the light was due to scintillations caused by the bombardment of the sulfide crystals by alpha particles, and that any element giving off such particles was effective.

In the self luminous radioactive-zinc sulfide phosphor preparations, the intensity of light is primarily dependent on the amount of alpha ray emitting radioactive material and the sensitivity of the phosphor to such radiations.

The sensitivity factor is of considerable importance since the specifications for self-luminous materials are generally based on "brightness" values and not on radioactive content.

There are a number of methods used for the determination of the sensitivity of zinc sulfide phosphors to alpha radiation. Some procedures involve the use of short wave length light and the measurement of the phosphorescent and fluorescent brightness. A more definite method is to incorporate the radioactive material in the phosphor and make measurements of brightness over a period of time. However, this method is exacting and time consuming.

In other methods, the phosphor is exposed to alpha radiations. Either a solid radioactive material or the gas radon is used as a source of alpha ray emitting materials.

It was through the use of radon as a source of alpha radiation for the evaluation of sensitivity in radium luminous zinc sulfide phosphor research investigations that an anomalous luminescent effect was found. When radon was confined over a plane surface of zinc sulfide phosphor, the luminosity was uniform for only a comparatively short time. The initial uniform brightness slowly changed to bright and dark areas having a

[1] Manuscript received February 14, 1949. This paper prepared for delivery before the Philadelphia Meeting, May 4 to 7, 1949.

variety of unpredictable configurations and these areas continued to change slowly their form and light intensity with time.

The original discovery was made when a number of samples of different zinc sulfide phosphors were placed in a small partially evacuated desiccator into which a few millicuries of radon (15 to 40 millicuries) were introduced. The first luminosity was quite uniform over the surfaces of the various individual phosphors, the brightnesses varying among the samples in accordance with their sensitivities. However, the luminosities did not remain constant. Light and dark areas appeared which continued to change slowly and over a period of several days did not return to the original uniform surface brightness.

At first it was believed the effect might be connected in some way with the desiccator acting as a condenser. To eliminate this factor, as far as possible, the inside surface was coated with a conducting medium and grounded. The changes in luminosity continued and apparently the type of containers (metal or non-metal) for the phosphors or their positions on on or off a grounded plate within the desiccator made no difference in the effect noted.

Further investigations led to the discovery that the boundaries of the light and dark areas arranged themselves roughly along the lines of the earth's magnetic field. A considerable number of experiments have been made, using imposed magnetic fields as well as the earth's field, but no plausible explanation of the effect has been proposed. However, the phenomenon is apparently connected in general with certain factors involved in the following observations:

1. The luminosity is due primarily to alpha radiations.
2. A magnetic field affects the position, type, and change in the luminous configurations. Either pole of a magnet is effective and the luminosity changes are noted whether the magnet is in the same plane as the phosphor or perpendicular to it. When perpendicular, the luminosity variations appear in general to center under the pole and to radiate from it.
3. The effect is connected with radon concentration. Low initial concentration may give no discernible configuration and any of the configurations which form slowly die out with the natural decay of the radon.
4. The luminosity is apparently due to radioactive material on the crystals of the phosphor. If a section of the surface of the phosphor is displaced after a configuration is set up, the luminosity remains unchanged and in the same position on the displaced portion.
5. The effect occurs whether or not there is a free movement of the phosphor crystals.
6. The total luminosity, over the entire surface of the phosphor, dark and light areas together, appears to remain somewhat constant. However, this is not a general rule as the total brightness is affected by the area of the phosphor in relation to the size of the container and the concentration of radon present as well as to the natural decay of the radon itself.
7. The configurations are changed or eliminated by rotating the surface of the phosphor. In general, the result of each rotation is to produce a practically uniform surface brightness followed by the formation of new configurations.
8. The configurations are not duplicated when planes of the phosphor are placed one above the other in the same radon atmosphere.

9. The size and form of the containing vessel have some effect on the type of configurations.

Under conditions of high luminosity it was found possible to photograph the effect without film fogging. An apparatus (Fig. 1) was assembled which proved satisfactory for photographing the effect. A pipe section 'A' ($2\frac{1}{2}$ in. ID) (6.45 cm.) was hermetically sealed with wax at its base 'B' and around the contact with the clear glass plate 'C.' A flat receptacle 'D' contained the phosphor, (ZnS). The radon, contained in a small capillary glass tube, 'F' ("seed"), is crushed in the rubber 'policemen' 'E,' the gas entering the apparatus through the side tube.

The diffusion of the radon into the space over the phosphor results in the production of the initial uniform luminosity. Photographs of the effect have been taken intermittently through a number of experimental runs with exposures of from 30 seconds to one minute without fogging. Two representative groups of the photographs are shown in Fig. 2 and 3.

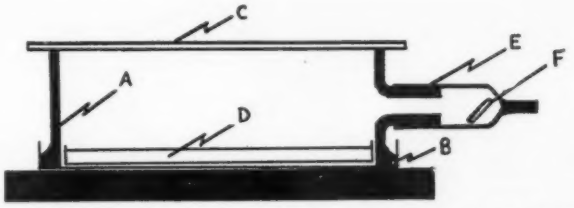

FIG. 1. Apparatus for photographing luminescent effect. A—pipe section, B—seal, C—clear glass plate, D—phosphor (ZnS), E—side tube and lock, F—radon "seed."

Fig 2. records some of the changes when a magnet is placed in the plane of the phosphor with the field in position to accentuate that of the earth. The first photograph was taken immediately after the introduction of the radon. Time data are indicated for each photograph taken throughout the period of the experiment.

Fig. 3 shows photographs of representative configurations when a magnet is placed in a perpendicular position to the plane of the phosphor. Time data were not recorded, but the photographs are characteristic of the effect under the condition indicated.

There is a similarity between the effect described and some of the auroral displays and, very recently, reference has been made to experiments in which magnetic lines of force have been made visible (1). However, it is admitted that no definite reason for the effect of radon over zinc sulfide phosphor has been suggested.

Further experiments are contemplated which include studies of such factors as the active deposit alone, variations of magnetic flux strengths, variations in pressure (ionization and range of particles) within the equipment, and the influence of the presence of different gases. This work may throw some light on the real cause of the effect, but it is hoped the presentation of the somewhat meager information so far found will interest others in the problem.

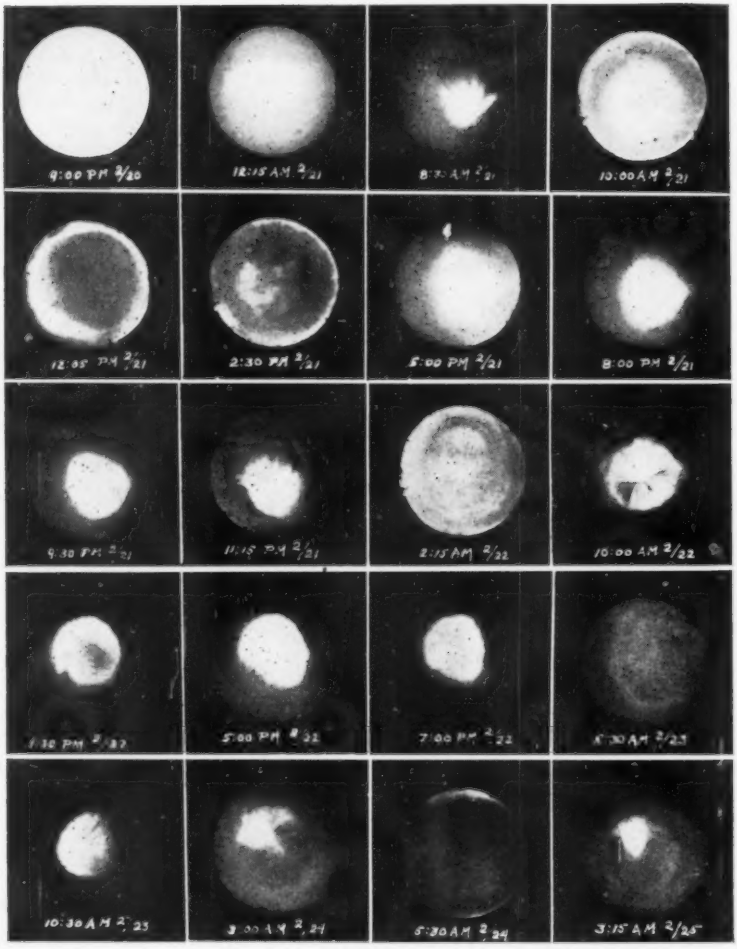
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FIG. 2

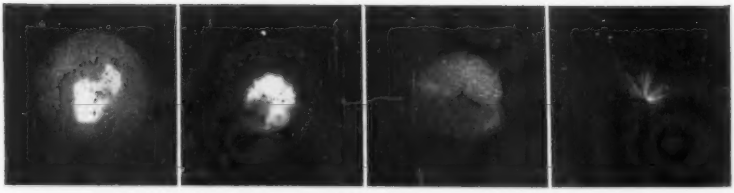

FIG. 3

ACKNOWLEDGMENT

The information indicated in this paper has been the result of experiments carried out over the period of a number of years as supplies of radon were available. I am indebted to a considerable number of physicists and chemists for assistance in endeavoring to explain the effect, and, in particular, to the Radium Emanation Corporation of New York, whose personnel has cooperated in giving the benefit of their experience and, in addition, contributed so generously of the radon used in many of the later experiments.

Any discussion of this paper will appear in the discussion section of Volume 95 of the TRANSACTIONS of the Society.

REFERENCE

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ELECTRODEPOSITION OF RHENIUM FROM AQUEOUS SOLUTIONS[1]

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ABSTRACT

A study of the electrodeposition of rhenium from aqueous plating baths, with emphasis on semi-quantitative information about cathode current efficiencies, is reported. Rhenium can be plated as a shiny, metallic, and adherent cathode deposit from several different types of aqueous baths, but the cathode current efficiencies were quite low, ranging from about fifteen per cent to less than one per cent. The sulfuric acid bath was found to be the most satisfactory rhenium plating bath. A new citric acid type of plating bath for rhenium is also described.

INTRODUCTION

A number of different aqueous solutions for the electrodeposition of rhenium have been reported. In 1934, Fink and Deren (1) proposed several plating baths for rhenium including a sulfuric acid bath, a phosphate bath, and an oxalate bath; of these the sulfuric acid bath seemed to be the best. They reviewed the earlier work of Holemann (2) and others and suggested that failures were perhaps due to a lack of appreciation and control of such factors as pH, temperature, and cathode current density. Two patents (3) on rhenium plating claim that hard, adherent rhenium plates can be obtained from aqueous solutions of pH 0.3 to 3.0 containing soluble rhenium compounds and an inorganic or organic acid other than a nitrate or a compound of fluorine. The recommended conditions are a bath temperature of 0° to 100°C. and a cathode current density of 8 to 17 amp./dm.^{2} In 1935, Anderson (4) published a brief note on rhenium plating. Young (5) used a modified sulfuric acid bath for the electrodeposition of rhenium on brass.

Several attempts have been made to use electrodeposition as a quantitative method for the determination of rhenium. Lundell and Knowles (6) used a dilute sulfuric acid solution, but found that they were unable to remove the last traces of rhenium. O. and F. Tomicek (7) developed a micro electro-analytical method, also using the sulfuric acid bath. They found, however, that approximately 0.2 per cent of the rhenium was left in solution and that the cathode deposits weighed on the average about 2.5 per cent more than the actual amount of rhenium in the solution, indicating the presence of oxides in the deposit. Voigt (8) used an ammoniacal solution for his electro-analytical method.

There is very little quantitative information available in the literature concerning the characteristics of the various aqueous baths proposed for the electrodeposition of rhenium. Present day interest in the chemistry of rhenium (9) and the lower cost of rhenium compounds suggest that

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such information may be of value. The purpose of this work is to present semiquantitative experimental work dealing with the electrodeposition of rhenium and to suggest other aqueous baths. The desired information about the baths was obtained best by noting the effect of changes in bath pH, bath composition, cathode current density, and bath temperature on current efficiency and appearance of the cathode deposits, and then comparing the results. Preliminary work showed that the sulfuric acid bath and two new baths, a citric acid bath and an ammoniacal citrate bath, were among the most satisfactory, so, detailed studies were limited to these three baths. Then, for the sake of completeness, the cathode current efficiencies of other proposed aqueous baths were determined.

MATERIALS AND METHODS

Preparation of plating baths.—The source of rhenium for all baths was potassium perrhenate ($KReO_4$) as this is the most readily available rhenium compound. The sulfuric acid bath of Fink and Deren (1) contained $KReO_4$ and concentrated H_2SO_4 to give the desired pH; the new citric acid bath contained 50 g./l. of citric acid and $KReO_4$; and the new ammoniacal citrate bath contained 50 g./l. of citric acid, potassium perrhenate, and concentrated NH_4OH to give a pH of about 9.5. A fresh bath was used for each electrolysis. The bath pH was determined by a glass electrode at the operating temperature of the bath.

Electrodes.—Platinum anodes, 3 x 3 cm., and copper cathodes of the same size were used in this work; the copper cathodes were carefully cleaned by the usual methods. During electrolysis, the cathode was supported between two anodes by brass buss-bars. It is recognized that this arrangement of electrodes is not the best for the measurement of exact cathode current efficiencies; however, it is felt that it is satisfactory as a means of comparing the various baths.

Electrolysis.—About 80 to 100 ml. of plating solution were used for each electrolysis. Pyrex beakers (150 ml.) which served as plating cells were placed in a thermostat to maintain the desired bath temperature. Ordinarily two cells were used for each 15 minute electrolysis run. The cells were covered with notched glass plates to minimize losses by spattering and evaporation. A copper coulometer was used in series with the plating cells. A variable voltage rectifier supplied direct current for electrolysis. The gain in weight of the cathodes in the plating cells and in the coulometer supplied the information necessary for calculating cathode current efficiencies.

Hull cell.—The Hull cell had a capacity of 267 ml. of plating solution and was used with a platinum anode and a copper cathode.

EXPERIMENTAL RESULTS

Effect of $KReO_4$ concentration on cathode current efficiency (C.C.E.).—In this study, the amount of $KReO_4$ in each bath was varied from 1 to 10 g./l. The sulfuric acid bath contained enough H_2SO_4 to give a bath pH of 1; the citric acid bath contained 50 g./l. of citric acid at a pH of 1.5; the ammoniacal citrate bath contained 50 g./l. of citric acid and NH_4OH to give a pH of about 9.5. The temperature of each bath was 70°C.; cathode current density (C.C.D.) was 8 amp./dm.^{2}; the time of

each electrolysis run was 15 minutes. A C.C.D. of 8 amp./dm.^{2} was used because preliminary results with the Hull cell showed that this current density gave bright plates with all the baths. The results are given in Fig. 1 and show, as expected, that the $KReO_4$ concentration has a marked effect on the C.C.E. of all three baths, and that the sulfuric acid bath has the highest current efficiency. All the cathode deposits obtained were bright and metallic in appearance.

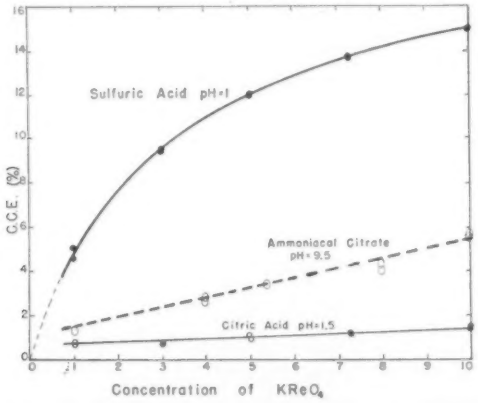

FIG. 1. The effect of the concentration of potassium perrhenate (g./l.) on the cathode current efficiency (C.C.E.) of the sulfuric acid, citric acid, and ammoniacal citrate rhenium plating baths. Temp. 70°C.; C.C.D. 8 amp./dm.^{2}; 15 minutes electrolysis.

Effect of bath temperature on C.C.E.—For these studies bath temperatures were varied from 25°C. to 90°C. To conserve the supply of $KReO_4$, each bath was made up to contain only 1 g./l. of $KReO_4$. It is recognized that this is a rather low concentration, but it was considered satisfactory because a fresh bath was used for each run and the period of electrolysis was short. Bath pH, C.C.D., and time of electrolysis were the same as noted above. The results given in Fig. 2 show that, for each bath, the C.C.E. increases with increasing bath temperature reaching a maximum at the highest bath temperature. Again the sulfuric acid bath gave the best C.C.E., a maximum of about 5 per cent at 90°C. It is obvious, on examination of Fig. 1 and 2, that the C.C.E. values given in Fig. 2 could be improved by using baths containing more $KReO_4$. All cathode deposits were bright and metallic in appearance.

Effect of pH on the C.C.E.—The sulfuric acid bath contained 1 g./l. of $KReO_4$ and H_2SO_4 to the desired pH. The C.C.D. was 8 amp./dm.^{2} and the temperature was 70°C. The upper limit for bright plates at these conditions was found to be about pH 1.4 to 1.5. Solutions less acid than this, e.g., pH 2, gave dark cathode deposits and a C.C.E. of less than one per cent. Solutions containing more H_2SO_4, e.g., pH 0.4 and lower, gave shiny metallic deposits with efficiencies of 4 to 6 per cent.

The citrate bath contained 1 g./l. of $KReO_4$, 50 g./l. of citric acid, and NH_4OH to the desired pH. The C.C.D. was 8 amp./dm.^{2} and the temperature was 70°C. Bright metallic cathode deposits were obtained in the pH range 1.5 to about 10. The best current efficiencies were observed in the pH range 6 to 7 (about one per cent) and in the pH range 9.5 to 10 (about two per cent).

When the pH of a bath containing 1 g./l. of $KReO_4$ and 50 g./l. of citric acid was adjusted with sodium hydroxide solution, the C.C.E. was

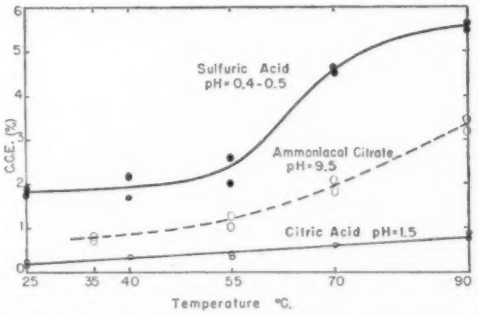

FIG. 2. The effect of bath temperature on the cathode current efficiency (C.C.E.) of the sulfuric acid, citric acid, and ammoniacal citrate rhenium plating baths. 1 g./l. of $KReO_4$; C.C.D. 8 amp./dm.^{2}; 15 minutes electrolysis.

TABLE I. *Cathode current efficiencies of various rhenium plating baths; 1 g./l. of $KReO_4$; temp. 70°C.; C.C.D. 8 amp./dm.^{2}*

Bath	pH	Approx. C.C.E.
		per cent
Citric acid, 50 g./l.	1.5	0.6
Citric acid, 50 g./l. + NH_4OH	10	2.0
Citric acid, 50 g./l. + NaOH	10	0.4
Oxalic acid, 62.5 g./l.	0.8	0.3
Na_2HPO_4, 66 g./l. + H_3PO_4	2.3	0.2
Sulfuric acid	1.5	5
Tartaric acid, 70 g./l.	1.3	0.5

found to be very low (about 0.3 per cent) and did not change in the pH range 4 to 12.

Cathode current efficiencies of other rhenium plating baths.—To compare current efficiencies of the various other rhenium plating baths, a number of them were prepared to contain 1 g./l. of $KReO_4$ and other ingredients and pH values as indicated in Table I. Current efficiencies were determined in all cases at a C.C.D. of 8 amp./dm.^{2} and a bath temperature of 70°C. As shown in Table I, all current efficiencies were quite low.

DISCUSSION AND CONCLUSIONS

There appears to be no difficulty in electroplating bright metallic deposits of rhenium from various types of aqueous plating baths. Cathode current

efficiencies in all baths are quite low and change considerably with bath concentration and electrolysis conditions.

Probably the most satisfactory bath so far reported for electroplating rhenium is the sulfuric acid bath of Fink and Deren (1). When this bath contains 10 g./l. of $KReO_4$ and H_2SO_4 to a pH of about one, it yields bright metallic cathode deposits, and, at 8 amp./dm.^{2} and a bath temperature of 70°C., the C.C.E. is about 15 per cent. When this bath contains only 1 g./l. of $KReO_4$, the C.C.E. at the same conditions is 5 per cent. This sulfuric acid bath is particularly sensitive to pH changes, which suggests that the fundamental reduction reaction may be represented by the equation

$$ReO_4^- + 8H^+ + 7e = Re + 4H_2O$$

The ammoniacal citrate bath is perhaps the best of the other plating baths studied. C.C.E. with this bath is quite low, but where it is necessary to conserve rhenium salts and where only a thin plate of rhenium is desired, it may be a useful bath.

The electrodeposited rhenium has a silvery metallic appearance but it tarnishes somewhat on standing, particularly in moist air. Rhenium metal gives no apparent reaction with HCl and very little if any reaction with H_2SO_4. It is soluble in H_2O_2 and in HNO_3 being oxidized to perrhenic acid, $HReO_4$.

It was observed by Fink and Deren (1) that rhenium can be codeposited with such metals as nickel and cobalt. A study of the electrodeposition of rhenium alloys is in progress in this laboratory and the results will be presented in a later article.

Any discussion of this paper will appear in the discussion section of Volume 95 of the TRANSACTIONS of the Society.

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THE EFFECT OF SODIUM HYDROXIDE UPON THE ELECTRODEPOSITION OF ELECTRODIALYZED KAOLIN[1]

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ABSTRACT

Fractions of electrodialyzed Georgia kaolin of definite particle-size range were prepared by centrifugation and employed to make suspensions for obtaining pH titration curves with NaOH as base. Using the same partly neutralized suspensions from the pH measurements, the corresponding yield in g./coulomb upon electrodeposition was determined.

Additional evidence was obtained that clay acts similarly to a weak monobasic acid upon titration, and that the following hyperbolic relation holds approximately for the yield upon electrodeposition at any pH:

$$\text{milliequivalents NaOH/100 g. clay (g./F)} = 10^5.$$

A simple mathematical explanation of this relation is presented, based upon the Henderson-Hasselbalch equation for the titration of weak acids.

The cell vessel used for electrodeposition constituted the metal anode in order to afford an even deposit of cylindrical shape, which could be handled with minimum loss. The yield of clay varied with the kind of metal employed as anode. Most of the experiments were performed using silver, which gave maximum yield of the various metals tried. This suggests the advantage of silver-plating anode equipment for the electrophoresis of clay.

INTRODUCTION

Few papers have been published giving definite information concerning the electrodeposition of clay, which is an anodic phenomenon. In a study of electrophoretic filtration of kaolin, Ralston and Hoseh (1) found that the Faraday equivalent of clay varied widely and suggested the importance of further study. Speil and Thompson (2) investigated the effect of numerous variables upon the electrophoretic dewatering of various clays with special reference to the moisture content, yield in g./F (grams per Faraday), and energy consumption for the product. They showed that, if the titration of electrodialyzed clay is regarded as the neutralization of a weak monobasic acid by a strong base, the product of milliequivalents of Na^+ per 100 g. clay and the corresponding yield of clay in g./F (or apparent molecular weight) is equal to the constant 10^5 at the end point.

[1] Manuscript received November 22, 1948. This paper prepared for delivery before the Philadelphia Meeting, May 4 to 7, 1949. Published by permission of the Director, Bureau of Mines.

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Also, if the particle charge is assumed to be proportional to the amount of Na^+ added, the same hyperbolic relation should hold at any stage of the titration. This was found to be approximately the case by experiment.

This branch of the subject, dealing with the titration of clay compared with yield upon deposition, is so complex that a further and more detailed study seemed warranted. In planning the present work, it was decided to concentrate upon experiments with different particle size fractions of the same electrodialyzed clay and with NaOH as dispersant. To obtain deposits of even thickness that would withstand handling and weighing with minimum loss, an improved cell was designed in which the vessel was metallic and served as anode.

EXPERIMENTAL METHODS

Fractionation of clay.—Approximately 5 kg. of washed kaolin from the Georgia Kaolin Company, Dry Branch, Georgia, was dispersed in distilled water by use of a propeller-type stirrer. The material less than 1 micron in diameter was separated from the coarser portion by 4 repeated sedimentations. This fine material was then further fractionated by repeated centrifuging in a Sharples continuous supercentrifuge according to the methods employed by Norton and Speil (3), to give three fractions designated respectively as: (1) minus 0.2 μ; (2) 0.2 to 0.5 μ; and (3) 0.5 to 1.0 μ.

Purification of clay by electrodialysis.—The clay suspensions were purified by electrodialysis in three compartment (Mattson-type) cells with dimensions 25 x 18 x 22 cm. Carbon anodes and copper cathodes with dimensions 23 x 18 cm. and spaced 10 cm. apart were employed. Parchment paper supported by cotton cloth served as the electrode membranes. Continuous stirring was maintained during the electrodialysis. An initial potential of approximately 100 volts was applied to the electrodes and gradually increased to approximately 600 volts as the conductivity of the suspension decreased. The water in the electrode compartments was replaced by distilled water at frequent intervals, hourly at first, and at approximately 8- and 12-hour intervals as the electrodialysis became more complete. The electrodes were interchanged at the end of each interval in order to redisperse the clay deposit from the anode membrane.

In order to obtain information on the completion of electrodialysis, a cell containing only distilled water was treated in the same manner as the cells containing clay suspensions. The pH values of the discharged water in the electrode compartments of this cell were measured at the end of 12-hour intervals of continuous electrodialysis and compared with those of the corresponding samples from the clay suspension cells. The pH values of the water and the clay suspension in the mid-compartments of the respective cells were also compared at the end of each time interval. A summary of a typical set of data is shown in Table I. The electrodialysis was considered complete when the pH of the catholyte water, after a 12-hour interval of continuous electrodialysis, remained constant, with a value between 8.0 and 8.6. It is to be noted that the pH of the clay suspensions was only slightly lower than that of the electrodialyzed water.

Apparatus.—In the electrolytic deposition experiments, a cylindrical anode, closed at the bottom with a No. 11 rubber stopper, served as the container for holding the clay suspensions. The cylinders, approximately

6 cm. in diameter and 10 cm. in height, were made from 0.127-inch-thick (0.323 cm.) sheet silver. For comparison purposes, anode cylinders were also made from sheet copper, lead, tin, zinc, and platinum. The maximum usable deposition area was about 130cm.^{2} The cathode consisted of a rotating silver-plated iron tube 1 cm. in diameter and 10 cm. in length, supported concentrically with respect to the anode and insulated from the electric motor by a glass rod. Unless otherwise stated, all data in this paper upon the electrodeposition of clay are based upon the use of silver anodes to receive the deposits.

Procedure.—Many exploratory experiments were performed, but the experimental procedure for the reported data was essentially as follows. Upon completion of the electrodialysis, which usually required 6 to 10 days, the exact concentration of the suspensions was determined by evaporating a weighed sample to dryness. The stock suspensions were then stored in large Pyrex Erlenmeyer flasks.

TABLE I. *Typical data showing pH of water and clay suspensions in cell compartments after approximately 12-hour intervals of continuous electrodialysis*

Hours of continuous electrodialysis	pH of catholyte from cells containing		pH of anolyte from cells containing		pH of mid-compartment sample from cells containing	
	Distilled water	Clay suspen.	Distilled water	Clay suspen.	Distilled water	Clay suspen.
24	9.7	11.3	3.0	3.2	4.5	—
48	7.9	11.0	2.7	2.8	—	3.5
72	8.2	10.5	2.8	2.7	—	—
96	8.6	9.4	2.7	2.6	4.3	4.2
120	—	7.8	—	2.7	—	3.8
144	—	8.5	—	—	—	—
168	—	8.1	—	—	—	3.8

The titration and electrodeposition experiments were made on constant weight samples of 5 and 10 per cent suspensions. The calculated amount of the stock suspension was weighed into a clean, dry 250-ml. Erlenmeyer flask, and the desired volumes of standard alkali and water were added from 10- and 100-ml. burettes, respectively. The flask was then closed with a rubber stopper and shaken on a vibratory bottle shaker for 24 hours. Measurements of pH were made at the end of the shaking period.

With fraction 1 these measurements indicated that the exchange reaction was not complete after 24 hours, and the shaking of this fraction was continued until the total time was 33 hours.

The entire sample was next poured into the electrolytic deposition vessel, and the clay was deposited. The anode metal cylinder had been previously cleaned, rinsed in alcohol, oven-dried, and weighed. In most of the deposition experiments, an attempt was made to keep the depletion of the samples low and approximately constant. This was done by using relatively small currents, 10 to 90 ma. or 0.08 to 0.7 ma./cm.^{2}, and by varying either current or time or both factors to yield fairly constant weights of clay. In some experiments, the current density for a given current was varied by changing the exposed area by means of Bakelite

cement. The yields of clay per coulomb appeared independent of the current density, which agrees with the observations of Speil and Thompson (2). All experiments were run at room temperature—about 25°C. The low current and short time employed prevented any appreciable temperature rise in the cell.

After the deposition was finished, the depleted suspension was carefully poured from the cell into a container for the respective fraction. The rubber stopper was removed from the anode vessel, and the cylinder with clay deposit was carefully dipped once in a large beaker of distilled water, allowed to drain for a few seconds, wiped dry on the outside with a cloth, oven-dried at 110°C. for 1½ hours, and weighed. The clay deposit was fairly dry and adhered well to the metal cylinder except with the fine fraction 1, where the deposit was very moist and tended to run. In some cases,

TABLE II. *Typical titration and electrodeposition data for 5 per cent suspensions of fraction 2**

Cell no.	Base per 100 g. dry clay	0.1062 *N* NaOH	Water added	pH before deposition	pH after deposition	Current	Time	Weight of dry clay	Yield of dry clay
	me.	*ml.*	*g.*			*ma.*	*sec.*	*g.*	*g./coulomb*
1	0	0	84.3	4.0	4.1	10	100	0.857	0.857
2	0.25	0.242	84.1	4.6	4.7	14	100	1.106	0.790
7	0.50	0.483	83.8	5.0	5.1	16	100	1.075	0.630
3	1.00	0.965	83.3	5.6	5.6	16	100	0.860	0.537
5	4.00	3.86	80.4	6.4	6.4	27	100	0.526	0.195
8	6.00	5.79	78.5	6.6	6.7	90	100	1.331	0.148
	7.00	6.76	77.5	6.8	—	—	—	—	—
	8.00	7.72	76.6	7.0	—	—	—	—	—
9	9.00	8.69	75.6	7.2	8.0	70	200	1.055	0.0754
4	10.00	9.65	74.6	8.4	9.4	90	200	1.186	0.0658
	11.00	10.62	73.7	9.9	9.7	—	—	—	—
	12.00	11.58	72.7	10.3	10.2	—	—	—	—
	13.00	12.54	71.8	10.6	—	—	—	—	—
	14.00	13.52	70.8	10.7	—	—	—	—	—

* Each portion of suspension was prepared by adding the specified amounts of NaOH solution and H_2O to 120.7-g. slip containing 8.49% dry clay.

the depleted suspensions of the respective fractions were treated with a slight excess of sodium hydroxide and electrodialyzed for use in later experiments.

Experiments as outlined were run on 5 and 10 per cent suspensions of fractions 2 and 3 and on a 5 per cent suspension of fraction 1. Data for a typical experiment are given in Table II.

In titrated clay suspensions, the equivalent weight of the clay is usually not known, and it is the practice to express the result in terms of milliequivalents of base per 100 grams of dry clay (me./100 g.).

Precision of measurements.—The pH measurements were reproducible within one-tenth of a pH unit. The g./coulomb value of dry clay, however, showed considerable deviation under similar experimental conditions. A total of 29 separate time experiments with groups of two to seven designed to give identical results were run. Three of these deviated from the group average as much as 10 per cent and four as much as 5 per cent. The

average deviation was approximately 4 per cent, which is slightly more than the maximum error involved in measuring the milliamperes in certain ranges. Such large deviations are probably explained by the fact that a small error in the amount of base, added near the isoelectric point where a majority of the trial experiments were run, causes a very large difference in the amount of clay deposited per coulomb. The adjustment of current by means of manual manipulation of resistors also introduced some error. While it is probable that small changes in the clay concentration do not markedly affect the g./coulomb values, the concentration decrement was not exactly constant for each of the deposition experiments that is, the weight of the clay deposit varied slightly for the runs of a given series.

TABLE III. *Titration and electrodeposition data for 5 per cent suspensions of fraction 2*

NaOH added per 100 g. dry clay	pH	Current	Time	Deposit of dry clay	Yield of dry clay
me.		*ma.*	*sec.*	*g.*	*g./coulomb*
0.00	4.0	10	100	0.86	0.86
0.25	4.6	14	100	1.11	0.79
0.50	5.0	16	100	1.08	0.68
1.00	5.6	16	100	0.86	0.54
2.00	6.1	30	100	1.14	0.38
3.00	6.3	40	100	1.19	0.30
4.00	6.4	27	100	0.53	0.20
6.00	6.7	90	100	1.33	0.15
7.00	6.8	—	—	—	—
8.00	7.0	—	—	—	—
9.00	7.2	70	200	1.06	0.076
10.00*	8.4	90	200	1.19	0.066
11.00	9.9	—	—	—	—
12.00	10.3	—	—	—	—
13.00	10.6	—	—	—	—
14.00	10.7	—	—	—	—

* End point 10 me.

RESULTS

Typical titration and electrodeposition data are shown for the 5 per cent suspensions of fractions 2 in Table III. The relation between the pH values of the various suspensions and the base added in me./100 g. of dry clay for the same fraction is shown graphically in Fig. 1. The titration curves for all fractions were very sharp, as illustrated. The base in me./100 g. required for complete neutralization of fraction 3, containing the larger particles, was 60 per cent of that required for fraction 2, containing the medium-size particles, and 44.5 per cent of that required for fraction 1, containing the smaller particles, or 6, 10, and 13.5 me./100 g., respectively.

The 5 per cent suspensions of fraction 3, which was the coarsest fraction, reached a higher pH than the 10 per cent suspensions at the same me./100 g. This would be expected from the lesser surface of the 5 per cent suspensions. For fraction 2, however, which was the intermediate fraction, the 5 and

10 per cent suspensions reached nearly the same pH. No comparison is available for fraction 1.

The 10 per cent suspensions for fractions 2 and 3 gave higher yields than the 5 per cent suspensions at the same me./100 g. This would also be expected, because of the lower charge of the 10 per cent suspensions, which at least is indicated by lower pH for fraction 3 as mentioned above.

This relation is in general agreement with the data of Speil (4) and with theory which would require that the milliequivalents of base be a linear

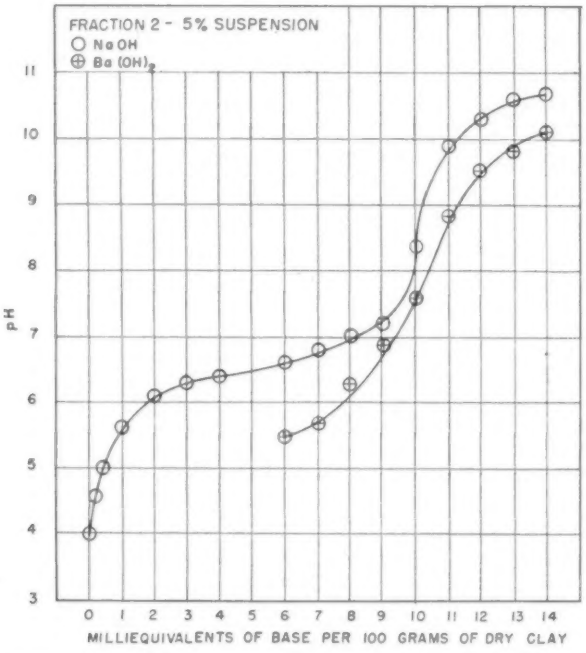

FIG. 1. Comparison of titration curve of five per cent suspension of fraction 2 with NaOH and $Ba(OH)_2$.

function of the surface area which in the case of a given weight of equal spherical particles is inversely proportional to the particle diameter. Here the relation would be more complex since the size distribution and exact shape of the particle would be involved. There was a slight discrepancy in the end point for the 5 and 10 per cent suspensions of fractions 2 and 3. The 5 per cent suspensions were prepared from the reelectrodialyzed 10 per cent suspensions and apparently the exchange reactions were not brought to exactly the same degree of completion as before.

In Fig. 1, titration curves for 5 per cent suspensions of fraction 2 with NaOH and $BA(OH)_2$ are shown. A comparison of the titration curves with NaOH and KOH were also made. The barium and sodium hydroxide

curves, as illustrated, were in approximate agreement, while the potassium and sodium hydroxide curves were practically identical. These results indicate that the hydroxyl ion is the important ion in the titration of a clay-OH-H particle. This is consistent with the findings of Johnson and Norton (5) but is contrary to some other reports in the literature.

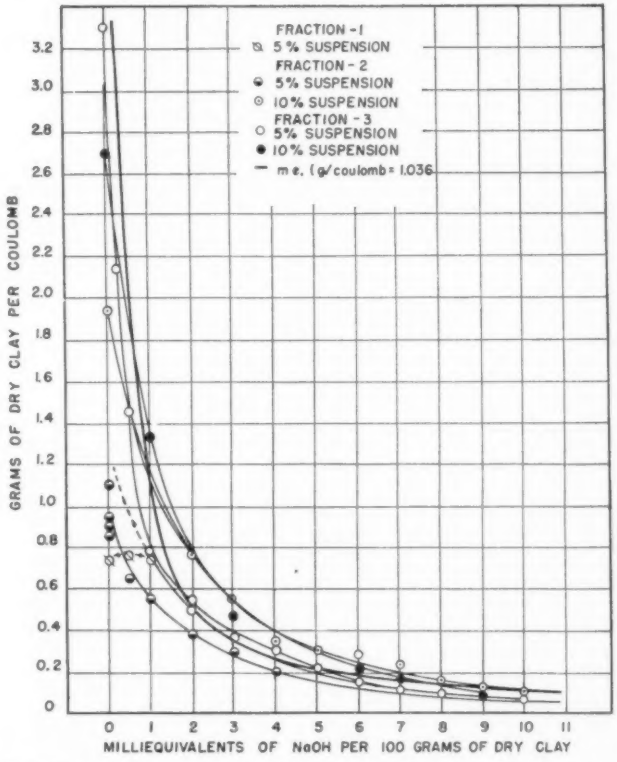

FIG. 2. Relation between grams of clay deposited and milliequivalents of base added.

The relation between the grams of dry clay deposited and the milliequivalents of base added for the different concentrations of the various fractions are shown together in Fig. 2. The theoretical equation:

$$\text{me.(g./coulomb)} = 1.036$$

which is derived in a later section is also presented for comparison. The satisfactoriness of the theoretical equation is satisfying.

The effect of different anode metals upon the g./coulomb yield of clay is shown in Table IV. These data are of considerable interest because

they show that the yield of dry clay, for a relatively inactive anode metal like silver, is almost twice as large as that obtained when using more active metals such as zinc, tin, lead, and copper. This might be interpreted to mean that the yield with a still more inactive metal like platinum would be even greater. This, however, is not true because the yield obtained with a platinum anode was about one-third of that obtained with a silver anode in a similar experiment. Considerable oxygen was evolved upon the platinum. The data of these experiments upon effect of anode metal and those found in the literature are not complete enough to offer satisfactory explanations for the results obtained, and show the need of further studies, in which anode corrosion and oxygen overvoltage should be considered.

TABLE IV. *Data showing effect of anode metal upon electrodeposition of electrodialyzed clay, using 5 per cent suspensions of fraction 3*

Run no.	Anode metal	Current	Time	Dry clay deposited	Dry clay deposited
		ma.	*sec.*	*g.*	*g./coulomb*
1	Ag	10	80	1.44	1.80
2	Cu	10	80	0.96	1.20
3	Pb	10	80	0.90	1.13
4	Sn	10	80	0.97	1.21
5	Zn	10	80	0.92	1.15
6	Ag	10	100	1.85	1.85
7	Cu	10	100	1.16	1.16
8	Pb	10	100	1.02	1.02
9	Sn	10	100	0.98	0.98
10	Zn	10	100	1.09	1.09

DISCUSSION

Theoretical.—The clay micelle may be considered as consisting of a kaolinite particle with negative ions adsorbed on certain unsaturated spots of its surface, with a higher concentration of miscellaneous positive counter-ions extending into the liquid phase. The complete electrodialysis of such a suspension produces a micelle with hydroxyl and hydrogen as adsorbed ions and counter ions, respectively. The hydrogen and hydroxyl ions are apparently closely associated, giving a low net negative charge. The fact that the suspensions are slightly acidic indicates that the bond between these ions is weaker than the similar water bond. The neutral micelle of the monodispersed clay particle and its ionization may be represented by the general formula:

$$\text{Clay } (OH)_nH_n = [\text{Clay}(OH)_nH_{n-m}]^{-m} + mH^+ \qquad (1)$$

and the titration of the suspension by the stepwise equation

$$\begin{aligned}
\text{Clay } (OH)_nH_n + OH^- &= [\text{Clay } (OH)_nH_{n-1}]^- + H_2O \\
\text{Clay } (OH)_nH_{n-1} + OH^- &= [\text{Clay } (OH)_nH_{n-2}]^{--} + H_2O \\
\text{Clay } (OH)_nH_{n-2} + OH^- &= [\text{Clay } (OH)_nH_{n-3}]^{---} + H_2O
\end{aligned}$$

$$\text{Clay } (OH)_nH_n + nOH^- = [\text{Clay } (OH)_n]^{-n} + {}_nH_2O \qquad (2)$$

It is assumed that all particles are charged at the same rate and that the total electronic charge is distributed uniformly among the dispersed particles. The mechanism of the titration of a weak monobasic acid such as acetic acid is shown by the equation:

$$CH_3COOH + OH^- = (CH_3COO)^- + H_2O \qquad (3)$$

One fundamental difference is observed between the two processes. In the latter, the essential reaction besides the formation of water is the ionization of the acetic acid, i.e., the *unit* charging of the acetate ion. In the former, as the titration progresses there is a *gradual* increase in the charge of each micelle. The charge increases from a minimum value at the beginning of the titration to a maximum value at the neutralization point. This means that the Faraday equivalent of the clay is necessarily a variable ranging from a very large maximum value for the nearly neutral particle obtained by electrodialysis to a much smaller minimum value for the completely charged particle, $[Clay\ (OH)_n]^{-n}$. The Faraday equivalent of the *acetate ion* remains constant at 59.04 g.

As there is but one point of inflection evident, the titration curves for the clay suspensions resemble those of weak monobasic acids rather than of weak polybasic acids. This condition is probably caused by the hydroxyl-hydrogen bond at one point on the particle not being appreciably affected by the loss of a hydrogen ion at another point.

Mathematical.—The approximate equivalent weight of an unknown weak monobasic acid or the corresponding anion can be calculated from the well-known Henderson-Hasselbalch equation, provided its titration curve is known. Accordingly, it should be possible to find by analogy a satisfactory correlation between the true Faraday equivalent of the clay and the me./100 g. of base added at any point in the titration. The term true Faraday equivalent is used because the experimental or apparent value may fall short of the calculated value because of various electrodeposition phenomena and mechanical losses.

The following simple mathematical correlation is developed from the Henderson-Hasselbalch equation for weak monobasic acids:

$$pH = pK + \log \frac{(salt)}{(acid)} = pK + \log \frac{(Na^+)}{(acid)} \qquad (4)$$

The terms employed are defined as follows:

pK = $-\log$ K, where K is the ionization constant of the acid or clay;
also, pK = pH at the mid point of the titration where the amount of salt is equal to the amount of acid present.
ME. = Milliequivalents of base required to neutralize 100 grams of acid or clay.
me. = Milliequivalents of base added to 100 grams of acid or clay at any stage of the neutralization.
X = Faraday equivalent of clay or acid radical at the end point of the titration or when ME. milliequivalents of base per 100 grams clay have been added.
x = Faraday equivalent of clay or acid radical at any point when me. milliequivalents of base per 100 grams have been added. For a weak monobasic acid x = X and is constant.

By considering the concentration of the salt as that of the acid anion or the charged clay and to be proportional to the me. of base added, and the concentration of the unionized acid radical or uncharged clay to be proportional to (ME. − me.), equation (4) can be written in the form:

$$pH = pK + \log \frac{(me.)}{(Me. - me.)} \tag{5}$$

As previously mentioned, in the titration of a clay suspension a standard portion of 100 g. dry clay is employed for reference calculations instead of the gram-equivalent weight, which is usually unknown. If the same system is employed with a weak acid to afford better comparison with clay, by definition the following relation holds at the end point:

$$\frac{ME.}{1000} = \frac{100}{X}$$

$$ME.(X) = 10^5 \tag{6}$$

$$ME. = \frac{10^5}{X}$$

Substituting this value of ME. in (5), converting to the exponential form, and solving for X gives:

$$X = 1/me. \frac{10^{(pH-pK)}}{1 + 10^{(pH-pK)}} 10^5 \tag{7}$$

For acids, x = X = constant.

In this equation, the term $\frac{10^{(pH-pK)}}{1 + 10^{(pH-pK)}}$ represents fractional neutralization. For instance, at pH = pK, this term equals 0.5, etc.

It is well-known that acetic acid conforms to the requirements of the Henderson-Hasselbalch equation, and since no new assumptions were introduced in the derivation of equation (7), the gram-equivalent weight of acetic acid or of acetate ion in this case, should be accurately calculated by the use of existing titration data. Such calculations were made using the data of Walpole cited by Clark (6) and are shown in Table V. The calculated values of x agree fairly closely with the actual value of 59.04 for acetate ion except in the early stages of the neutralization, where the Henderson-Hasselbalch equation is less rigorous. In this treatment it should be emphasized that only approximations are employed because application to the clay system is too complex for any advanced considerations, no corrections for dilution, ionic strength, etc., have been attempted.

In order to apply equation (7) to the clay suspensions an additional assumption, mentioned early in this paper, is necessary. This requires that the charge on the clay micelle shall be directly proportional to the me./100 g. of base added up to the neutralization point. This is another way of stating as an approximation that the gram-equivalent weight of the clay at any point is inversely proportional to the me. of base added per 100 g. clay or:

$$X/x = me./ME., \quad \text{or} \quad X = \frac{me.}{ME.} x \tag{8}$$

Substituting this value of X in equation (7) and solving for x gives:

$$x = \frac{ME.}{(me.)^2} \frac{10^{(pH-pK)}}{1 + 10^{(pH-pK)}} 10^5 \quad (9)$$

This may be written in the form:

$$me.(x) = \frac{ME.}{me.} \frac{10^{(pH-pK)}}{1 + 10^{(pH-pK)}} 10^5 \quad (10)$$

TABLE V. *Equivalent weight of acetate ion, $(CH_3COO)^-$, as calculated by equation 7 from titration data in the literature (6)*

Acid neutralized	NaOH added	pH	Equivalent weight*
per cent	*me./100 g.*		
20	338.8	4.047	61.58
40	677.5	4.454	59.35
50	846.9	4.626†	59.04
60	1016.3	4.802	59.03
80	1355.0	5.227	59.00
100	1693.8	8.000‡	59.01

* Value from atomic weights is 59.04.
† pK.
‡ End point estimated by extrapolation of the titration curve.

By converting equation (5) into the expoential form directly and solving for $\frac{ME.}{me.}$, the reciprocal of the acid fraction titrated at any point, there is obtained:

$$10^{(pH-pK)} = \frac{me.}{ME. - me.}$$
$$\frac{ME.}{me.} = \frac{1 + 10^{(pH-pK)}}{10^{(pH-pK)}} \quad (11)$$

Substituting this value of $\frac{ME.}{me.}$ in equation (10) yields:

$$me.(x) = 10^5 = \text{constant} \quad (12)$$

Since (x) is equal to the grams of clay per 96,500 coulombs of electricity, by substitution we obtain the theoretical equation:

$$me.(g./coulomb) = 1.036 \quad (13)$$

This hyperbolic relation should be valid as long as the titration characteristics of the clay suspensions with a strong base are similar to those of a weak monobasic acid, and can be compared with the relation of equation (6) for the *end point* of a weak acid. Based on the assumptions made, equation (12) indicates that a similar relation holds at *any point* of the neutralization of clay up to the end point. In equation (6) both factors at the left are constants, while in equation (13) both left factors are variables. Accordingly, when the grams of clay per coulomb of electricity

are plotted against the base added in me./100 g. an equilateral hyperbola should be obtained.

Comparison of data.—The ionization constants, which are of the same order of magnitude as the first ionization constant of carbonic acid (4.52×10^{-7}), (7) were obtained for the various clay suspensions from the respective titration curves and are shown in Table VI. The values of me.(x) calculated from equation (10) are given in Tables VII to XI inclusive. The equivalent weights calculated from equation (9) and (12) are also compared in the same tables.

TABLE VI. *Ionization constants of the electrodialyzed clay suspensions*

Fraction	Concentration of clay by weight	Ionization constant
	per cent	
1	5	4.47×10^{-7}
2	5	3.16×10^{-7}
3	5	0.80×10^{-7}
2	10	5.62×10^{-7}
3	10	3.16×10^{-7}

TABLE VII. *Data showing calculated values of me.$(x)(10^{-5})$ and $x(10^{-5})$ compared with Faraday equivalent obtained from electrodeposition for 5 per cent suspensions of fraction 3*

NaOH added per 100 g. dry clay, me.	pH	me.$x(10^{-5})$ (calculated from equation 10)	$x(10^{-5})$ (calculated from equation 9)	$x(10^{-5})$ (calculated from equation 12)	g./F (10^{-5}) (experimental)
0.0	4.5				3.2
0.25	5.4	0.5	2.0	4.0	2.0
0.50	5.9	0.7	1.4	2.0	1.4
1.00	6.4	1.0	1.0	1.0	0.8
2.00	7.0	1.3	0.7	0.5	0.55
4.00	7.2	0.8	0.20	0.25	0.29
5.00	7.4	0.8	0.16	0.20	0.19
6.00*	8.6	1.0	0.17	0.17	0.14
7.00	9.8	0.9	0.13	0.14	0.11

* End point of titration = 6.0 me.

If the values at the beginning of the titration where the amount of base added is small are neglected, the calculated values of me.(x), shown in column 3 of the tables, are fairly constant and agree reasonably well with the theoretical value of 10^5. The neglect of the suggested values is permissible since the Henderson-Hasselbalch equation is not rigorous at this point. The agreement, otherwise, is as good as the accuracy of the pH measurements warrant, except in a few cases. This means that the titration curves of electrodialyzed clay suspensions do resemble those of weak monobasic acids.

While there is approximate agreement between the calculated and experimental gram-equivalent weights for the suspensions of fraction 3 shown respectively in columns 4, 5, and 6 of Tables VII and VIII, in most cases there is only rough agreement for the fractions 2 and 1, or the finer

fractions, as shown in columns 4, 5, and 6 of Tables IX, X, and XI respectively. When the complexity of the problem and the simplicity of the assumptions are considered, however, the agreement in all cases can be considered fairly good. The better agreement obtained with the suspensions of fraction 3, is probably due to the fact that complete electrodialysis and ionic exchange were more easily obtained with the larger particles.

TABLE VIII. *Data showing calculated values of me.$(x)(10^{-5})$ and $x(10^{-5})$ compared with Faraday equivalent obtained from electrodeposition for 10 per cent suspensions of fraction 3*

NaOH added per 100 g. dry clay, me.	pH	me.$(x)(10^{-5})$ (calculated from equation 10)	$x(10^{-5})$ (calculated from equation 9)	$x(10^{-5})$ (calculated from equation 12)	g./F (10^{-5}) (experimental)
0.0	4.0				2.6
1.00	5.8	1.2	1.2*	1.0	1.3
3.00	6.4	1.0	0.33	0.33	0.44
5.00	6.8	0.9	0.18	0.20	—
6.00	7.0	0.9	0.15	0.17	0.21
7.00*	8.6	1.0	0.14	0.14	0.15
8.00	9.8	0.9	0.11	0.13	—
9.00	10.4	0.8	0.09	0.11	0.08

* End point of titration = 7.0 me.

TABLE IX. *Data showing calculated values of me.$(x)(10^{-5})$ and $x(10^{-5})$ compared with Faraday equivalent obtained from electrodeposition for 5 per cent suspensions of fraction 2*

NaOH added per 100 g. dry clay, me.	pH	me.$(x)(10^{-5})$ (calculated from equation 10)	$x(10^{-5})$ (calculated from equation 9)	$x(10^{-5})$ (calculated from equation 14)	g./F (10^{-5}) (experimental)
0.0	4.0				0.83
0.25	4.6	0.5	2.0	4.0	0.76
0.50	5.0	0.6	1.2	2.0	0.66
1.00	5.6	1.1	1.1	1.0	0.52
2.00	6.1	1.4	0.7	0.5	0.37
3.00	6.3	1.3	0.43	0.33	0.29
4.00	6.4	1.1	0.28	0.25	0.19
6.00	6.7	1.0	0.17	0.17	0.14
7.00	6.8	0.95	0.14	0.14	—
8.00	7.0	0.95	0.12	0.13	—
9.00	7.2	0.93	0.10	0.11	0.073
10.00*	8.4	1.0	0.10	0.10	0.064
11.00	9.9	0.91	0.08	—	—
12.00	10.3	0.83	0.07	—	—

* End point of titration = 10.0 me.

The gram-equivalent weights calculated from equation (12) and shown in column 5 of the tables are independent of experimental errors in the pH measurements including the pK values. In many cases, the gram-equivalent weights calculated from equation (12) are in closer agreement than those calculated from equation (10), with the experimental values

based upon electrodeposition and given in column 6 of the tables. This is particularly true with the suspensions of fraction 1, the finest fraction.

TABLE X. *Data showing calculated values of* $me.(x)(10^{-5})$ *and* $x(10^{-5})$ *compared with Faraday equivalent obtained from electrodeposition for 10 per cent suspensions of fraction 2*

NaOH added per 100 g. dry clay, me.	pH	$me.(x)(10^{-5})$ (calculated from equation 10)	$x(10^{-5})$ (calculated from equation 9)	$x(10^{-5})$ (calculated from equation 12)	$g./F\ (10^{-5})$ (experimental)
0.0	3.9				1.9
2.0	5.8	1.2	0.60	0.50	0.74
3.0	6.0	1.1	0.37	0.33	0.51
4.0	6.2	1.1	0.28	0.25	0.34
5.0	6.3	1.0	0.20	0.20	0.31
6.0	6.4	0.91	0.15	0.17	0.28
7.0	6.6	0.92	0.13	0.14	0.20
8.0	6.9	0.95	0.12	0.13	0.17
9.0*	7.7	1.0	0.11	0.11	0.13
10	9.2	0.93	0.093	0.10	0.09
11	10.4	0.85	—	—	—

* End point of titration = 9.3 me.

TABLE XI. *Data showing calculated values of* $me.(x)(10^{-5})$ *and* $x(10^{-5})$ *compared with Faraday equivalent obtained from electrodeposition for 5 per cent suspensions of fraction 1*

NaOH added per 100 g. dry clay, me.	pH	$me.(x)(10^{-5})$ (calculated from equation 10)	$x(10^{-5})$ (calculated from equation 9)	$x(10^{-5})$ (calculated from equation 12)	$g./F\ (10^{-5})$ (experimental)
0.0	3.6				0.70
0.5	4.2	0.19	0.38	2.00	0.73
1.0	4.6	0.24	0.24	1.00	0.71
2.0	5.4	0.68	0.34	0.50	0.47
3.0	5.8	0.99	0.33	0.33	0.35
6.0	6.3	1.1	0.18	0.17	0.14
10.0	6.9	1.1	0.11	0.10	0.07
11.0	7.0	1.0	0.09	—	—
12.0	7.3	1.0	0.08	—	—
13.0*	8.2	1.0	0.07	—	—
14.0	9.1	0.96	0.07	—	—
15.0	10.1	0.90	0.06	—	—

* End point of titration = 13.5 me.

This investigation was discontinued due to the emergency of war work. Future experiments employing more refined experimental technique are desirable to test more rigorously, the validity of the concepts involved.

SUMMARY AND CONCLUSIONS

From these incomplete experimental data the following conclusions appear to be warranted:

1. Further evidence was obtained that electrodialyzed kaolin reacts like a weak monobasic acid when titrated with a strong base.

2. Additional evidence was obtained that the yield of electrodialyzed kaolin, when titrated to various degrees with a strong base and then electrodeposited, follows approximately the hyperbolic relation:

$$\text{me.NaOH/100g. clay (g./F)} = 10^5$$

The probable yield of clay (g./F) can be estimated from this expression, or from the titration curve at any corresponding point of the latter.

3. A simple mathematical explanation of this relation is presented, based upon the Henderson-Hasselbalch equation for the pH during neutralization of a weak acid.

4. Silver as anode metal was found to afford a higher yield of clay than copper, lead, tin, zinc, or platinum and was, therefore, employed in most of the work. This suggests the advantage of silver plating anode equipment for the electrophoresis of clay. At present, the yield for a given metal cannot be predicted.

5. An improved form of cell was devised for electrodepositing clay to afford deposits which can be handled and weighed with minimum loss.

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Any discussion of this paper will appear in the discussion section of Volume 95 of the Transactions of the Society.

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Choosing A Profession

The young man is fortunate who can choose his profession easily and wisely. Some know from their earliest years what they want to do, but more often the choice of a profession is a haphazard affair made with little knowledge of the nature and requirements of the profession or of the specific talents of the individual. Many never really choose a profession but are led by economic conditions or chance acquaintance to undertake a given course of training. Others enter professional training lacking the requisite mental aptitudes.

Intellectual capacity appears to be inherited. There is even evidence that quality of mind is dependent upon certain combinations of genes. For example, it has been shown that talent for musical performance has a hereditary basis. It is logical to suppose that creative ability, that essential characteristic of scientific minds, is inborn although this is more difficult of genetic proof. In any case, these potential capacities require environmental stimulation if they are to be discovered and developed. It is here that professional men can be of assistance by presenting information on the nature, requirements, and opportunities in their professions. The medical, dental, and legal groups have local representatives in most communities who can stimulate and advise talented prospects for careers in these fields. In contrast, practitioners of the physical sciences and engineering are less often available to supply information concerning their fields. Consequently, young people are dependent for the most part upon their teachers in secondary schools and colleges for knowledge of these professions. It is in an effort to contribute information concerning the field of electrochemistry that the Journal will begin next month a series of articles on the Profession of Electrochemistry by men distinguished in its various branches.

Electrochemistry is a broad subject. On its scientific side, it is closely associated with physics and chemistry. Indeed the electrochemical scientist must be broadly trained in the whole field of the physical sciences and in mathematics. It is in engineering that electrochemistry as a profession is well defined. Comprising a large segment of modern industry such as primary and secondary batteries, electronics, electrodeposition, and the electroprocess industries, electrochemistry offers a diversity of important engineering careers. Specific knowledge of these fields should assist young men in choosing a profession.

R. M. B.

Current Affairs

Philadelphia Promises Interesting Program

The Electrochemical Society will return to its birthplace for its Spring Convention on May 4, 5, 6, and 7, 1949. When the small group of interested scientists met in Philadelphia to organize the Society in 1902, their hopes and expectations could hardly have visualized today's organization of world-wide scope, with members from practically every country on the globe.

The Convention Committee of the Philadelphia Section is preparing a well-rounded program with adequate provision both for the scientific sessions and the social functions. The committee is composed of Ernest G. Enck, General Chairman, and the following subcommittee chairmen: Harry A. Alsentzer, Entertainment; Milton B. Barba, Plant Visits; Russell P. Heuer, Hotel Reservations; John F. Gall, Meeting Accommodations; Edgar L. Eckfeldt, Registration; Hiram S. Lukens, Finance; Albert A. Ware, Publicity. Working with them are the officers of the Philadelphia Section: R. H. Cherry, Chairman; J. L. Crenshaw, Vice-Chairman; J. F. Hazel, Secretary; Arthur Osol, Treasurer.

The Convention will be held in the Benjamin Franklin Hotel, 9th and Chestnut Streets, Philadelphia, where the very successful Spring Meeting of 1937 was held. The Benjamin Franklin is located in the heart of the shopping and theatrical district and is only a few blocks from Independence Hall, Carpenters Hall, the Betsy Ross House, Christ Church, and other historic buildings.

Ladies' Program

A special feature of the May meeting will be the program for the ladies. Entertainment Chairman Alsentzer has organized a ladies' committee who will see that the convention wives are entertained in proper style while their husbands are attending the scientific sessions. Details of the program will be announced in succeeding issues of the JOURNAL.

Scientific Program

A very important feature of the program of the meeting will be the Symposium on Theoretical Electrochemistry under the chairmanship of Professor George Glockler of the State University of Iowa. This symposium will include papers by such well-known authorities as Professor V. K. La Mer of Columbia University, Dr. H. A. Abramson of the College of Physicians and Surgeons, Dr. Karl Soliner of the U. S. Public Health Service, Professor K. G. Stern of Brooklyn Polytechnic Institute, Dr. J. L. Oncley of Harvard Medical School, Dr. H. A. Laitinen of the University of Illinois, Professor Glockler and Dr. J. W. Sausville of the State University of Iowa, and others.

Dr. Abramson's subject is "Applications of Electrophoresis to Allergy." Dr. Solmer will discuss "Some Recent Work on the Electrochemistry of Membranes." The title of the paper by Professor Glockler and Dr. Sausville will be "Electron Affinity of Carbon."

In view of the interest shown at the meeting in Columbus last Spring, the Electronics Division is planning to sponsor symposia on Rare Metals and Luminescence at the Philadelphia meeting. An encouraging number of papers have been received from outstanding scientists in the field of Electronics and the program promises to be an outstanding one. A list of some of the papers to be presented at these symposia will appear in a forthcoming issue of the JOURNAL.

Round Table Discussion

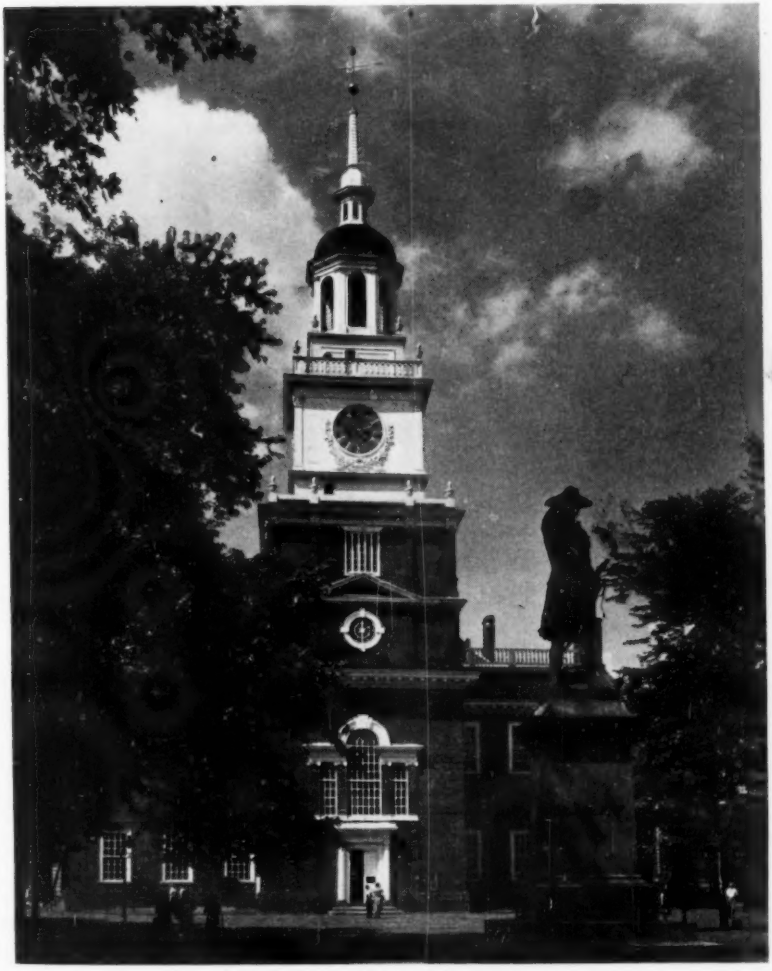
"Materials of Construction for Chlor-Alkali Plants" is the subject of a round table discussion planned by the Industrial Electrolytic Division for the Convention. The subject will be approached from two directions, i.e., (1) from the standpoint of requirements of various processes, and (2) from the standpoint of the properties of various processes.

Chlor-alkali producers and equipment suppliers will have the opportunity of drawing upon the experience of many experts in the field for the discussion of their problems.

Since time is short and the scope of the round table unlimited, it would be helpful in the preparation of a rough outline to have suggestions or contributions of special interest communicated, in advance of the meeting, to the Secretary of

the Division: M. S. Kircher, Hooker Electrochemical Company, Niagara Falls, New York.

The program for the Convention as planned by the Convention Committee, and the various Divisions which are sponsoring symposia promises to be a successful one. Electrochemical Society conventions are planned to offer a varied and interesting program for all members and guests. A convention may offer much to the member, but the ultimate success of any meeting depends upon those who attend. It is hoped, therefore, that members, and others interested in electrochemistry, will plan now to attend the Spring Meeting of the Society in Philadelphia.



INDEPENDENCE HALL, PHILADELPHIA

Candidates for President

Alfred L. Ferguson

Alfred L. Ferguson has been a member of the Society since 1918, and is now senior Vice-President, having long been active in Society affairs.

Dr. Ferguson was born on June 6, 1884, at Grass Lake, Michigan. He received his M.A. degree from the University of Michigan in 1909, and his Ph.D. degree in 1915. For the past thirty-seven years he has taught at Michigan, where he is now Professor of Chemistry. Twenty-one men have received the Ph.D. degree in Electrochemistry under his supervision.

His principal fields of research are polarization and overvoltage, and electroplating; his total publications on these and related subjects now total fifty-nine.

Dr. Ferguson belongs to several professional and learned societies, including Alpha Chi Sigma, Phi Lambda Upsilon, Gamma Alpha, Sigma Xi, the American Chemical Society, and the American Electroplaters' Society. He has recently been appointed to direct two research projects for the latter organization, one on Adhesion of Electrodeposits, the other on Polarization and Overvoltage.

ALFRED L. FERGUSON

Sherlock Swann, Jr.

Sherlock Swann, Jr., became a member of the Society in 1928. He was a Manager from 1934 to 1940, Vice-President from 1941 to 1943, and Manager again from 1943 to 1946. In addition, he was Secretary-Treasurer of the Electro-Organic Division, 1940–42; Vice-Chairman, 1942–44; and Chairman 1944–46.

Dr. Swann has been on many committees of the Society, and has been a representative of the Chicago Section. At present, he represents the Electro-Organic Division on the Publication Committee, and is a member of the Ways and Means Committee.

Dr. Swann was born in Baltimore, Maryland, on September 30, 1900. He received his B.S. degree from Princeton University in 1922, and his Ph.D. degree in organic chemistry from Johns Hopkins University in 1926.

He became a member of the Division of Chemical Engineering, Engineering Experiment Station, University of Illinois, in 1927, and has been Research Professor of Chemical Engineering since 1941. His principal research is in the field of electro-organic chemistry.

SHERLOCK SWANN, JR.

Candidates for Vice-President

Erwin F. Lowry

Erwin F. Lowry joined Sylvania in February, 1940, and for the past five years has been Manager of Fluorescent Engineering.

Dr. Lowry took his undergraduate work and Masters degrees in Chemistry at Ohio Wesleyan University and his Ph.D. in Physics at Ohio State where he was instructor in Physics.

Since leaving Ohio State, he has been engaged in industrial research, primarily in electronics. He has obtained some thirty U. S. Patents and is the author of about 14 technical articles on various electronic subjects, particularly oxide coated cathodes and problems connected with fluorescent lamps. He was responsible for the adoption of nickel as a filamentary material for radio tube use and is the inventor of Konal—the first of the filament alloys so widely used at the present time.

He has been a member of The Electrochemical Society since 1945 and is at present Secretary-Treasurer of the Electronics Division. He is also Vice-Chairman of the Light Source Committee of the Illuminating Engineering Society.

ERWIN F. LOWRY

J. C. Warner

J. C. Warner became a member of the Society in 1922 and has served as Chairman of the Publication Committee, the Weston Fellowship Committee, and the Roeber Research Fund Committee.

Born in Goshen, Indiana, May 28, 1897, he attended Indiana University where he received the degrees A.B. in 1919, M.A. in 1921, and Ph.D. in 1923. After varied industrial and teaching experience, he joined the faculty of Carnegie Institute of Technology in 1926, becoming Professor and Head of the Department of Chemistry in 1938. From 1939 to 1943, he worked on the investigation of the corrosion problems at the Panama Canal, and as a supervisor of research on synthetic rubber. From 1943 to 1945 he was granted leave by Carnegie to serve on the Manhattan Project. Returning to Carnegie, he held his former position and was made Dean of Graduate Studies.

Dr. Warner is a member of many technical and honorary societies, serves as Chairman of several important scientific committees, has written and contributed to technical books, and is consultant to the Argonne National Laboratory.

J. C. WARNER

Candidates for Secretary and Treasurer

Henry B. Linford

Candidate for Secretary

Henry B. Linford was born in Logan, Utah, on April 23, 1911. He received his B.S. degree from Utah State College in 1931, his M.S. degree from State College of Washington in 1933, and his Ph.D. at Washington in 1936. In 1936–37, he did additional graduate research at Columbia as a Weston Fellow of The Electrochemical Society.

HENRY B. LINFORD

Dr. Linford became a research chemist at the American Smelting and Refining Company in Perth Amboy, N. J., in 1937. In 1941 he was appointed instructor in chemical engineering at Columbia University and was made an assistant professor in that department in 1946.

He is a member of the American Chemical Society, the American Electroplaters' Society, and holds an associate membership in the American Institute of Chemical Engineers. In addition, he is a member of Sigma Xi, Phi Lambda Upsilon, and Alpha Chi Sigma.

Dr. Linford has been a member of The Electrochemical Society since 1936 and at present is Chairman of the Electrodeposition Division.

E. Gideon Widell

Candidate for Treasurer

E. Gideon Widell at present serves the Society as Chairman of the Electronics Division and as a member of the Board of Directors. He has been active in Society affairs since he joined in 1930.

Born in St. Paul, Minnesota, July 21, 1890, he attended the University of Minnesota receiving the B.S. degree in 1917. He served in the first world war

E. GIDEON WIDELL

Chemical Warfare Service for two years following, and then received an M.S. degree in 1921 from Massachusetts Institute of Technology.

Mr. Widell joined the research staff of the Westinghouse Lamp Division and became one of the first to work on the modern version of the oxide-coated electron emitter which is used in most radio receiving tubes at the present time.

In 1930, Mr. Widell became a member of the research staff of the Radio Corporation of America, Victor Division, Harrison, New Jersey, where he has continued his chemical and physical researches in electronics. He has been granted many United States and foreign patents on electronic discharge devices.

H-VW-M Opens New Laboratory

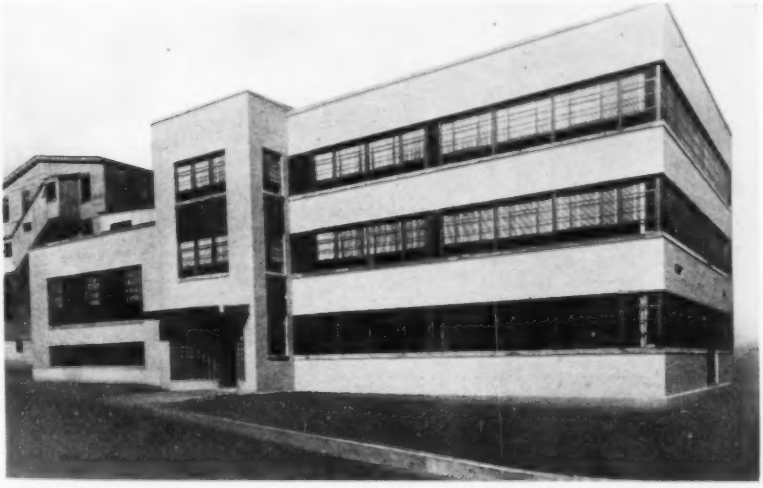
The formal opening of the new Hanson-Van Winkle-Munning electrochemical laboratory at Matawan, N. J., was celebrated November 17th. In observance of the occasion, representatives of the press, technical societies, and prominent individuals in public life were invited from all parts of the country to take part in the opening-day program which consisted of company-conducted inspection tours of the new building, the dedication, and a reception on the premises.

The H-VW-M laboratory, with its more than 15,000 square feet of floor space, is one of the finest structures specifically designed and erected for the sole purpose of carrying on experimental and service work in the electroplating and polishing field. It contains the most advanced facilities available for research and development in the industry and for helping individual companies in the industry to solve their everyday problems.

Heart of the new three-story laboratory is the plating room on the first floor. Equipment installed here includes complete apparatus for experimental and sample cleaning, pickling, plating, and anodizing. Here will be conducted most of the final tests from which will come concrete recommendations and contributions to the industry. Forty-two feet wide and sixty-three long, the plating room is the culmination of many years of intensive planning. The equipment includes virtually every known device for scientific operation of electroplating solutions. Efficiency, advanced instrument control, comfort and safety of technicians, accessibility of services and, most important of all, sufficient flexibility in the arrangement of apparatus, to permit alterations to meet changing needs, were major considerations in the set-up.

The floor is covered with acid-proof bricks which are pitched in various directions to the drainage troughs under each line of tanks. Silicon-iron waste lines carry drainage to an outside treatment plant. Overhead, vapor-proof fluorescent fixtures provide uniform lighting for night work, while continuous window areas on two sides combine with highly reflective walls and ceilings to eliminate the need for artificial light during normal daylight hours.

A complete air change can be made in the plating room every 1½ minutes, if



Exterior View of the New Hanson-Van Winkle-Munning Company, Matawan, N. J., Laboratory

desired, through ducts that provide cooled air in the summer and warmed air in the winter. Air to replace that drawn out is furnished through a louvered duct from the outside. Three exhaust blowers and one intake fan keep the room under slight pressure, thus keeping out dust and preventing contamination of plating solutions. Current is supplied by two d.c. motor generator sets, one with a 1500 ampere capacity at 6–12 volts and the other a 500 ampere, 40 volt unit. Portable low-voltage rectifiers are available for auxiliary d.c. current.

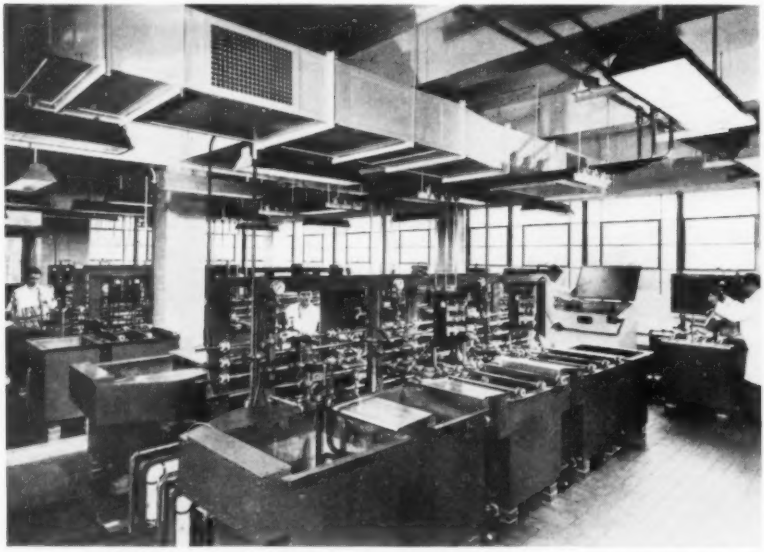
A large analytical laboratory on the second floor is used primarily for customers service, involving the analysis of plating solutions and investigating difficulties encountered in the application of electrodeposits. The research laboratory is devoted to the investigation of new products and processes and fundamental studies of problems related to metal finishing. Both departments are equipped with double fume hoods with built-in, flush-mounted, six kilowatt hot plates, Diggin Electroplating Control Tables, and provisions for replacing air withdrawn by hoods with forced, filtered, fresh air. Additional rooms on the floor house a metallographic laboratory, dark room, balance room, and offices.

In the right wing of the second floor is a laboratory for investigating, developing, and testing polishing and buffing compounds and materials. A feature of this laboratory is a custom-built, precision buffing machine used for exact valuation of buffing and coloring compositions, as well as for basic research.

An intercommunication system closely links the laboratory's 33 rooms.

H-VW-M officials expressed the double hope that everybody in the industry would visit the new laboratory and that companies in the industry would use the facilities as a pilot plant to determine correct solutions and cycles before changing over to new types of plating jobs. Since several technical societies have already scheduled their 1949 conferences in the new building, a good part of this wish seems well on its way to fulfillment.

The Hanson-Van Winkle-Munning Company has been a Sustaining Member of The Electrochemical Society since 1941.



PARTIAL VIEW OF PLATING ROOM SHOWING STANDARD PROCESS TANKS AND EQUIPMENT FOR CLEANING, PICKLING, AND PLATING

Section News

Chicago Section

The meeting of the Chicago Section, held at the Chicago Engineers' Club on November 5th, opened with a report from the Section's representatives, Dr. Sherlock Swann, Jr. and Mr. O. W. Storey, to the Local Section Advisory Committee meeting held in New York on October 13th.

Clifford A. Hampel, Vice-Chairman of the Chicago Section and General Chairman of the committee handling the preparations for the National Convention in Chicago, October 12–15, 1949, reported on the progress being made to set up committees for the convention. He stressed the need for the support of the whole Chicago Section and suggested those who had a preference should communicate with him. The committees are: Finance, Registration, Meeting Arrangements, Entertainment, and Plant Trips.

The headline event of the evening was a talk entitled, "Molecular Radar" presented by Dr. George Glockler, Head of the Department of Chemistry and Chemical Engineering at the State University of Iowa. Following a brief theoretical review of the spectroscopic methods presently used in studies of molecular structure, Dr. Glockler described a method being advanced at Iowa.

The development of radar during the last war has opened a new approach in the study of molecular structure which is being rapidly exploited. Radar waves, 0.8–1.4 cm., excite the molecules into rotation. The rotational energy about the different axes is determined from the spectrograph. Using known values of atomic mass and the probable structure, the intramolecular angles and distances may be derived. Molecules particularly susceptible to this form of analysis are those having the tetragonal configuration, i.e., methane.

The relative values obtained by this means are very accurate and check well with those of other methods. One of the chief advantages is that the spectrograph is almost purely rotational. An obvious disadvantage is the complexity of the radar generating equipment. This problem has been handled nicely at the University of Iowa on a cooperative basis by the Chemistry Department which prepares the samples for analysis and the Physics Department which keeps the apparatus in trim.

Although the theoretical discussion was apart from the ordinary experience of a large proportion of the audience, the lucid explanations and dynamic demonstrations of the speaker held the attention of the audience throughout.

The talk was followed by a brisk discussion of the commercial aspects and applications of radar in this field. Dr. Glockler handled a difficult subject in an interesting and refreshing manner.

H. D. Douglas, *Secretary*

Detroit Section

The Detroit Section met at the Sheraton Hotel on October 22nd and was addressed by Dr. Alfred L. Ferguson, Head of the Department of Chemistry, University of Michigan, and Vice-President of The Electrochemical Society. Dr. Ferguson's interesting subject was entitled "Polarization and Overvoltage," the presentation including a discussion of definitions, basic concepts, methods and errors of measurement, the influence of determining factors and some electrochemical operations in which overvoltage plays an important part.

Dr. Ferguson stressed the fact that polarization is the inevitable consequence of all electrochemical reactions, regardless of whether they take place in a voltaic cell or in an electrolytic cell. The Daniell cell was used to illustrate the meaning of the fundamental concepts "solution pressure," "osmotic pressure," and "electrode potential." Dr. Ferguson defined polarization as "any change from the equilibrium potential of an electrode in a given solution due to the passage of current through the system." This potential may become greater or less. If, in a given case, it becomes greater, Dr. Ferguson refers to it as "positive polarization"; if it becomes less, he terms it "negative polarization."

Two types of polarization were distinguished, viz. (1) that due to changes in ion concentration in the electrolyte, and (2) that due to gas formation at the electrodes.

Dr. Ferguson emphasized the importance of polarization and overvoltage studies as a guide to the understanding of electrode phenomena. He then listed a numer of the unsolved problems in this field and discussed fifteen suggested mechanisms for the transformation of ionic hydrogen in solution into bubbles of hydrogen gas.

Several methods for measuring polari-

zation and overvoltage were described. These included (1) two methods employed by the speaker and his associates in which reference electrodes are located in *back* of the anode and cathode, (2) the customary method which involves locating the reference electrodes in front of the anode and cathode, and (3) the Haring Cell method. Dr. Ferguson plans a comparative study of these methods.

The speaker concluded his talk with a well-illustrated discussion of the various factors which influence polarization and overvoltage and the nature of this influence.

The Detroit Section held its next meeting on November 19th at the Sheraton Hotel and was addressed by Mr. R. L. Ledford of the Hanson-Van Winkle-Munning Corporation. His subject was "Nickel Deposits in Electroforming." In his discussion, Mr. Ledford dwelt on the methods of making electrolyses, with particular emphasis on control and composition of nickel in obtaining satisfactory nickel deposits.

The program for future meetings of the Detroit Section is as follows:

January 21—8:00 P.M.
Subject: Some Electrochemical Aspects of Neurophysiology
Speaker: Dr. Robert Gesill, Department of Physiology, University of Michigan

February 18—8:00 P.M.
Subject: To be announced
Speaker: Dr. D. T. Ewing, Michigan State

March 18—8:00 P.M.
Subject: To be announced
Speaker: Dr. Paul Winters, Research Laboratories, General Motors Corporation

April 15—8:00 P.M.
To be announced

May 20—8:00 P.M.
To be announced

M. L. Baty, *Secretary-Treasurer*

Midland Section

The Midland Section held a dinner meeting at Le Chateau in Bay City, Michigan, on November 3rd. H. E. Houser, of the Dow Chemical Company, reported to the Section at this time on the National Society Meeting at New York.

Following Mr. Houser's talk, the members discussed National Society affairs briefly, and suggestions were made for the operation of local sections, including membership drives, by-laws, etc. Program committees for 1949–50 were set up and the program for the present season, including speaking tours and plant trips, was considered.

The meeting was well attended and enjoyed by all.

F. W. Koerker, *Secretary-Treasurer*

New York Metropolitan Section

A fall dinner meeting was held by the New York Metropolitan Section at the Holley Hotel in New York on November 10th. The technical meeting followed the social gathering; Mr. Donal F. McCarthy, former Examiner at the U. S. Patent Office was the speaker and chose as his subject, "Some Observations Relating to Patents and Scientific Research."

Mr. McCarthy was unusually well qualified to discuss this subject as he is a graduate in chemical engineering as well as a patent attorney, and had been associated with many situations in which both talents were in demand. He is a Westerner by birth, and graduated from the University of Washington with a degree in chemical engineering, working in the Anaconda smelter in his spare time. Later he studied patent law at Georgetown University and became an Examiner at the U. S. Patent Office in Washington. He subsequently joined the firm of Pennie, Edmond, Morton and Barrows and was a partner for many years prior to his leaving in 1947 to engage in independent practice.

J. S. Mackay, *Secretary-Treasurer*

Philadelphia Section

The first meeting of the 1948–49 year of the Philadelphia Section was held November 3rd, in the Harrison Laboratory, University of Pennsylvania. A dinner at the Lenape Club in honor of the speaker, Professor N. H. Furman, preceded the meeting. Forty-seven members and guests attended the dinner, and about 75 attended the technical meeting.

Dr. Furman addressed the Section on "Trends in the Development of Electrical Methods of Analysis," covering recent developments in potentiometry, electrodeposition, and polarography. An illustration was given of the detection of impurities in uranium and its compounds by a combination of electrolysis and polarography. Application of polarography to the study of anthraquinone and its derivatives was outlined and a

comparison was made of the polarographic measurements with the oxidation-reduction potentials of these compounds.

Dr. Furman, Professor of Chemistry at Princeton University, is also a consultant to the U. S. Atomic Energy Commission. He recently was honored as the first recipient of the Fisher award in Analytical Chemistry.

J. F. HAZEL, *Secretary*

Personals

JAMES H. CONOLLY recently joined the Chicago staff of Graham, Crowley & Associates, Inc. Mr. Conolly was formerly with the Newton Falls Division of the Standard Steel Spring Company as electroplating and industrial waste disposal engineer. Mr. Conolly's new duties will involve research in the field of electrochemistry.

ROBERT S. DALRYMPLE has accepted a position as corrosion chemist for the Permanente Metals Corporation, Division of Metallurgical Research, Spokane, Washington. Mr. Dalrymple's work will be in the field of corrosion with regard to aluminum. He was formerly at Battelle Memorial Institute, Columbus, Ohio.

VASANT MADHAV DOKRAS has been appointed Deputy Director of Technical Education by the Government of the Central Provinces, Nagpur, India. Dr. Dokras had recently spent four years in the graduate school at Columbia University.

BERNARD A. GRUBER has joined the staff of the Battelle Memorial Institute at Columbus, Ohio. Mr. Gruber was formerly with the Harshaw Chemical Company, Cleveland, Ohio.

CHARLES L. MANTELL, consulting chemical engineer, has been appointed Chairman of the Department of Industrial Chemical Engineering at Newark College of Engineering, Newark, New Jersey.

CHARLES H. POINTER, has obtained a leave of absence from the School of Chemistry, Metallurgy, and Ceramics at the University of Alabama and returned to active duty in the Navy. He is stationed at the Naval Air Station, Pensacola, Florida, and is attached to the production division of the overhaul and repair department.

ALBERT B. SAMPLE recently resigned as head of the research analytical section of Smith, Kline & French Laboratories in Philadelphia, and is now employed as biochemist by the Laboratory of Clinical Pathology and the John S. Sharpe Research Foundation of the Bryn Mawr Hospital, Bryn Mawr, Pennsylvania.

Hugh J. McDonald Now at Loyola

Dr. Hugh J. McDonald was recently appointed Professor of Physical Chemistry and Chairman of the Department of Chemistry, Loyola University, School of Medicine, Chicago, Illinois. Until recently, he was Professor of Chemistry and Director of the Corrosion Laboratory at Illinois Institute of Technology, Chicago.

Dr. McDonald joined the staff at Illinois Tech in 1939, and founded the Corrosion Research Laboratory in 1944. He has served as Vice-Chairman of the Corrosion Division of the Society, as Secretary-Treasurer of the American Coordinating Committee on Corrosion, and as first Chairman of the University Conference on Corrosion and Metal Protection. He is currently serving as a member of the Board of Directors of the National Association of Corrosion Engineers, as editor of the Theoretical Section of the magazine *Corrosion and Material Protection*, and as a consultant to the Argonne National Laboratory.

Frank Savage Vice-Pres. at Graham, Crowley

Frank K. Savage has recently been elected Vice-President of Graham, Crowley & Associates, Inc. Previous to joining the Chicago research and development group of this firm, Mr. Savage had been engaged in the development of electroforming processes with C. G. Conn, Ltd., Elkhart, Indiana. There Mr. Savage was, successively, chemist, chief chemist, and general superintendent. Later he became superintendent of the Metals Division of Keuhne Manufacturing Company, Mattoon, Illinois, and after that Vice-President of the Standard Plating Rack Company, Chicago.

Mr. Savage will direct company efforts in connection with consultation, research, and development in the electroplating field in the middle west area to augment corresponding operations of the company in the eastern area with headquarters at Jenkintown, Pa.

New Members

At the meeting of the Executive Committee held on November 4, 1948, at the office of The Electrochemical Society, Inc., 235 West 102nd St., New York City, the following were elected to membership:

THOMAS S. BLAIR, mailing add.: The Iron Age, 100 E. 42 Street, New York 17, New York (Electrodeposition)

STEVEN H. BROWN, Enthone, Inc., mailing add.: 442 Elm Street, New Haven, Connecticut (Corrosion, Electrodeposition, Electronics, Electro-Organic, Theoretical Electrochemistry)

ALVIN A. CADWALLADER, Philadelphia Nickel Cadmium & Storage Battery Company, mailing add.: 7210 Gillespie Street, Philadelphia 35, Pennsylvania (Battery, Electrodeposition, Electronics)

JOHN G. DEAN, International Nickel Company, Inc., 67 Wall Street, New York 5, New York (Battery)

PHILIP H. DELANO, E. J. Lavino & Company, mailing add.: P. O. Box 29, Norristown, Pennsylvania (Battery, Electrodeposition)

ASHFORD B. FRY, The Dow Chemical Company, Magnesium Laboratories, 52 Building, Midland, Michigan (Battery, Corrosion, Electrodeposition)

NATHAN FRANK HELPER, States Batteries, Inc., mailing add.: 1 Arkansas Street, San Francisco, California (Battery)

WILLIAM P. INNES, G. M. Research Laboratory Division, mailing add.: 20114 Goulburn, Detroit 5, Michigan (Theoretical Electrochemistry, Organic Electrochemistry, Batteries, Corrosion, Alkali and Chlorine, Electrodeposition, Electrothermics, Electronics, Dielectrics, Power)

J. C. LANGFORD, Dominion Alkali & Chemical Company, Ltd., mailing add.: 2240 Sun Life Building, Montreal, Quebec, Canada (Industrial Electrolytic)

LAWRENCE M. LITZ, Philadelphia Nickel Cadmium Battery Company, mailing add.: 7204 Gillespie Street, Philadelphia 35, Pennsylvania (Battery, Electrodeposition, Theoretical Electrochemistry)

THOMAS ARTHUR REILLY, National Carbon Company, mailing add.: 13608 Gainsboro, East Cleveland, Ohio (Battery, Corrosion)

PIERRE VAN RYSSELBERGHE, mailing add.: Department of Chemistry, University of Oregon, Eugene, Oregon (Corrosion, Theoretical Electrochemistry)

IRVING S. YOUNG, U. S. Electric Manufacturing Corporation, mailing add.: 1130 Anderson Avenue, New York 52, New York (Battery)

New Sustaining Member

The National Battery Company, Gould Industrial Division, in Depew, New York, has recently become a Sustaining Member of the Society. Such generous support as provided by this organization is appreciated by the Society and, in particular, the Battery Division.

Two other battery firms, the Willard Storage Battery Company of Cleveland, Ohio, and the Electric Storage Battery Company of Philadelphia, Pennsylvania, became Sustaining Members of the Society last Spring.

A complete list of the Society's Sustaining Membership may be found on the back cover of this issue of the JOURNAL.

Meetings of Other Organizations

American Society of Heating & Ventilating Engineers, 55th annual meeting, Stephens Hotel, Chicago, Ill., January 24–27.

American Institute of Electrical Engineers, winter general meeting, Hotel Statler, New York City, January 31–February 4.

Edison Pioneers, 32nd annual luncheon and 31st annual meeting, place to be announced, February 11.

Essex Electrical League, fifth electrical exposition, Mosque Theatre Building, Newark, N. J., March 8–11.

Third International Lighting Exposition and Conference, Hotel Stephens, Chicago, Ill., week of March 28.

19th Annual Safety Convention and Exposition, Hotel Statler, New York City, March 29–April 1.

American Gas Association, Distribution, Motor Vehicle, and Corrosion Conference, Netherland Plaza Hotel, Cincinnati, Ohio, April 4–6.

National Electrical Wholesalers Association, 41st annual convention, Netherland Plaza Hotel, Cincinnati, Ohio, May 1–6.

American Gas Association Production and Chemical Conference, Hotel New Yorker, New York City, May 23–25.

Gas Appliance Manufacturers Association, annual meeting, Drake Hotel, Chicago, Ill., May 25–27.

Book Reviews

LITERATURE SEARCH ON DRY CELL TECHNOLOGY, WITH SPECIAL REFERENCE TO MANGANESE DIOXIDE AND METHODS FOR ITS SYNTHESIS by Marjorie Bolen and B. H. Weil. Published as Special Report No. 27 by State Engineering Experiment Station, Georgia Institute of Technology, Atlanta, Georgia, 1948. viii + 700 pages, $5.00 (U.S.A.), $5.50 (foreign countries).

This work which is a bibliography with abstracts, will be of interest to all those whose work deals with dry cell research, development, or manufacture. The authors are Mrs. Marjorie Bolen, Research Assistant, and Mr. B. H. Weil, Chief of the Technical Information Division, Georgia Institute of Technology. The search was sponsored by the Battery Branch, Signal Corps Engineering Laboratories, Fort Monmouth, New Jersey, under a contract with the Institute. The preparation and publication of this exhaustive work is a real contribution to the general dissemination of knowledge in this field.

Mr. Weil, in his preface, describes the scope of the search as constituting an indexed, expanded bibliography of the pertinent literature dealing with (1) dry cell technology, (2) manganese ore deposits throughout the world, and (3) methods of treating such ores for the preparation of depolarizing compounds, with particular attention to electrolytic processes for the production of manganese dioxide. Actually, the coverage is far wider, and includes much basic research information in addition to technology. It also covers a great many related fields, such as references to studies of primary cells other than the Leclanché type.

The book is divided into three main parts. The first consists of more than 1400 abstracts of technical papers. The second gives abstracts of 733 foreign patents and nearly 1600 U. S. patents. The final portion, 160 pages, is an index by subject matter of the material in the first two sections.

It appears to this reviewer that this bibliography is of the exhaustive rather than the critical type and will of necessity contain many references to work of little present value. However, a critical survey of the literature, if it is to be complete, must always be preceded by an all-inclusive one. For this reason, the present work should lighten immeasurably the burden of anyone engaged in a literature search of any field included within its scope.

The entries, except for patents, are listed alphabetically by authors. It would have been preferable, in this reviewer's opinion, had they been arranged by year of publication as this would facilitate the extension of existing bibliographies. However, this is a minor point, considering the general usefulness of this book. The authors are to be complimented on the thoroughness with which they have listed their source material and the subject headings under which searches were made.

The basic source for the technical literature appears to have been *Chemical Abstracts* from 1907–1947. Additional sources were *Engineering Index*, *Industrial Arts Index*, *British Abstracts*, and *Chemisches Zentralblatt*. The *Bibliography of Scientific and Industrial Reports* provided abstracts of government-issued reports on foreign technology prepared by teams sent to Germany, etc., to learn of wartime advances abroad.

Only one who has done extensive bibliographical work can appreciate the tremendous amount of painstaking effort required in the preparation of a book such as this and it is to be hoped that it will be used as widely as it appears to deserve.

U. B. THOMAS

PROCEEDINGS OF THE THIRD INTERNATIONAL ELECTRODEPOSITION CONFERENCE (Held in London, England on September 17 to 21, 1947, under the auspices of the Electrodepositors' Technical Society) Published by the Electrodepositors' Technical Society, 27 Islington High Street, London N.1, England, 1948. 219 pages, Price (to non-members) £ 2-10-0.

This publication contains the twenty-four papers which were presented at the Conference and the discussion stimulated by them. An exhibition held in conjunction with the Conference is described briefly. Representation from Europe, North and South America, India, Egypt, and Australia made this a truly international affair. The First International Conference was held in London in 1937 and the Second in New York in 1939, under the auspices of the American Electroplaters' Society.

The scope of the Third International Conference is indicated by the subjects

discussed, viz. (1) the electrolytic polishing of metals, (2) miscellaneous processes and reports, (3) electrodeposition processes, and (4) the structure of electrodeposits. The subject matter presented is of interest to theoretical and practical man alike.

P. A. Jacquet, credited with the discovery of electrolytic polishing, presented the first paper on this subject. Of particular interest is a bibliography of 161 references which accompanies this article.

In the symposium on miscellaneous processes, the plating practices of a number of countries were described. The chemical treatment of zinc surfaces was also discussed. Electrodeposition processes which were considered included those for depositing silver, copper, chromium, cadmium, heavy nickel, tungsten alloys, and alloys from sulfamate baths. The group of papers on the structure of electrodeposits is worthy of special comment. No one interested in this field can afford to neglect it. Contributors to this group included R. Piontelli, A. T. Steer, U. R. Evans, J. J. Dale, T. Banerjee, and G. E. Gardam.

The Electrodepositors' Technical Society and the American Electroplaters' Society are to be congratulated for promoting these highly successful conferences. They serve a very useful purpose and certainly should be continued.

H. E. Haring

From the Publishers

Chemical Process Principles, Combined Volume, by Olaf A. Hougen and Kenneth M. Watson. Published by John Wiley & Sons, Inc., New York, 1948. 1155 pages, $12.50.

A comprehensive volume, this book offers a thorough treatment of (1) Material and Energy Balances, (2) Thermodynamics, and (3) Kinetics and Catalysis. The preface states: "The present book continues to give intensive quantitative training in the practical applications of the principles of physical chemistry to the solution of complicated industrial problems and in methods of predicting missing physiochemical data from generalized principles."

Vacuum Manipulation of Volatile Compounds by R. T. Sanderson. Published by John Wiley & Sons, Inc., New York, 1948. 162 pages, $3.00.

This book, which is the first to describe the fundamental methods and apparatus involved in chemical high vacuum technique, makes it possible for anyone with an average scientific background to study volatile chemical compounds conveniently and accurately. Although the book is intended primarily for scientists unfamiliar with the high vacuum technique, it will also be valuable to experienced users as a reference.

Employment Situations

Please address replies to box shown, c/o The Electrochemical Society, Inc., 235 W. 102nd St., New York, 25, N. Y.

Positions Available

Corrosion Engineer, for pilot plant and laboratory research on corrosion problems of chemical and petroleum processes. Advanced education or several years equivalent experience desirable in chemical engineering, physical metallury and corrosion. Location California. *Reply to Box A-206.*

Recent Graduate, Chemical Engineer or Metallurgist, for supervised research and development for electrolytic metals refining plant. Training in electrochemistry and general knowledge of nonferrous metallurgy essential. Submit resumé and salary requirements. *Reply to Box A-207.*

Positions Wanted

Graduating Ph.D. in Chemical Engineering desires position in research. Two years industrial experience, three years naval officer experience. Age 28, married, one child. Middle Atlantic states location preferred. *Reply to Box 326.*

Electrochemist, Ch.E. with eighteen years extensive experience in many phases of electrodeposition, electroforming, metal finishing, etching, and related fields. Plant layout, installation development, research. Wide consulting background. Several outstanding developments in bright metal and alloy gold plating. *Reply to Box 327.*

Powder Metallurgist, graduate chemical engineer, 35, married, 13 years diversified experience in research, development, production in impregnated diamond tools, synthetic sapphire, cemented carbides, iron powder metallurgy, desires responsible position with progressive organization, preferably in diamond tool or in high temperature metal-ceramic field. *Reply to Box 328.*

Letters to the Editor

What Size Shall We Be?

Dear Sir:

Dr. Burns's recent editorial, "On Being the Right Size," (August, 1948) was most clever and fitting. I think we should go a step farther and use its qualitative message to work out a quantitative answer specifically for the needs of The Electrochemical Society. Just what would be the right "size" for our group?

Size, as I see it, should be defined not by mere number of the membership. It should embrace scope as well as quality of subjects covered and of the membership. Once these are set, the numerical optimum of membership may be determined more easily. A scientific Society with, say, 3000 first rate members would have far greater distinction than one with, say, 6000 of mixed background. The present appears to be an opportune time to take stock of past achievements and potentialities for the future.

While not too familiar with the other Divisions of the Society, I find that there is considerable improvement, in a "missionary" way, possible for the Electronics Division. By expanding it very considerably in both size and scope it would help to develop The Electrochemical Society to the point of broad physico-chemical prominence and diversity once occupied by the German Bunsen Gesellschaft and still enjoyed by the British Faraday Society. This would imply widening our field of interests to include more of theoretical and applied physical chemistry, instead of just electrochemistry and a few selected subjects of electronics. It would, of course, be in the direction of greater emphasis on science and the scientific foundation of practical applications (as against practical usage).

At the moment there is no American Society carrying out this job with whole devotion although, I believe, a need for it exists. The American Chemical Society has changed the orientation, even the name, of the *Journal of Physical Chemistry* toward predominance of colloid chemistry. *The Journal of Chemical Physics*, an affiliate of the American Institute of Physics, is interested in the physico-mathematical approach to physical chemistry. Many papers dealing with general physico-chemical subjects are scattered elsewhere. Unfortunately, there are many physical chemists who do not consider their work of first class unless it be published by a journal of physical denomination. I believe this is based on an unfounded feeling of inferiority and could be remedied.

It has also been argued that much of the physico-chemical work is of greater interest to the physicist than to the chemist and for this reason should be discussed before a physical forum. I do not share this opinion. I believe physical chemistry is a strong enough science in its own right to stand unsupported. However, it requires broad and earnest enough backing by a first rate society and journal. A competent and aggressive effort in this direction should be generally welcomed and will earn greater prominence and distinction for the Society, a healthy growth for present and future divisions, and a wider circulation of its JOURNAL.

H. C. FROELICH
Cleveland, Ohio

Ideas and Atoms

Dear Sir:

Your humble servant has four ideas, the last 4 of his 47 fundamental ideas which he knows will lead science, astronomy, nuclear physics, physics, engineering, and mathematics to a New Vista and which when fully developed by Scientists will lead to a revolutionary New Order. He craves the privilege of presenting these ideas to you in an appearance and lecture. In the Cincinnati Post of November 8th it says "No one knows what makes the atom nucleus hold together." I know and will divulge this in this lecture and give the answer to what the real atomic forces are.

JOHN A. WATTERSON
Cincinnati, Ohio

Clarification

Jack DeMent of Portland, Oregon, writes that he was not given an opportunity to see beforehand the item concerning him which appeared in "Look" magazine and which was reprinted in the July issue of the JOURNAL.—ED.

Feature Section

So You Want Your Paper Published

*C. L. Faust**

You've finished a commendable job of research or have in mind a fine discussion of timely interest that you want to write up and see in published form. Because your subject is in its field of interest, you desire publication by The Electrochemical Society.

Before you put your manuscript in final form, read "The Instructions to Authors of Papers," which is given on page 38*N* of the March issue of the JOURNAL. Recall that the Society requires the metric equivalent to be expressed for all units stated in English system. Prepare your charts, figures, and drawings with such density of line and lettering that they can be reduced to fit a 6 x 9 page without loss in clarity and legibility. Should you not be familiar with the proper size of the original, consult your local printer or write to the Secretary's office for a sheet of "Instructions to Authors." It shows a sample drawing for guidance. Also, put your references in complete form, using the official abbreviations for journals as adopted by *Chemical Abstracts*. These are simple requirements for uniformity in the bound TRANSACTIONS, in which many of the articles in the JOURNAL will subsequently appear. Negligence in these simple matters is very obvious in many recent manuscripts submitted to the Society. Delays result in getting manuscripts approved for acceptance.

For further guidance in preparing your paper, read O. W. Storey's feature on "Reviewing of Papers" in the February, 1948, issue of the JOURNAL. Mr. Storey describes the reviewing procedure and states the six questions each reviewer is asked to answer in regard to the manuscript. Here are the six questions:

1. Does the paper cover new material or a representation of old subject of timely interest?
2. Does the manuscript require rewriting or careful editing? Particularize if possible.
3. Can the subject matter be condensed to advantage, and if so, which parts?
4. Are there any inaccuracies of statement which may be called to the author's attention before the paper is printed?
5. Is there any other phase of this subject which should be included?
6. Do you recommend the paper for publication?

Ask yourself whether your paper can pass

C. L. FAUST

on each count. If you think it does, send it in. If you are doubtful about a point, revise the doubtful issue before mailing in the manuscript.

When you refer to the work of others, do not read only the abstract if it is at all possible to refer to the original article. This valuable admonition was suggested by Dr. U. R. Evans of England in a recent "Letter to the Editor" (June, 1948, issue of the JOURNAL).

The Publication Committee is anxious to have all papers in such form as to reflect credit on both the Society and the Authors. It exists to help, not to rule. Yet, it primarily must uphold the "quality" standards as much as possible and reject, or submit for revision, all manuscripts that are poorly written, contain inaccuracies of statement, and have important omissions. A decision

* Member of the Society's Publication Committee.

on quality is reached only after the paper has been reviewed by three or more experts in the field of technical interest in the paper.

Authors should not and cannot expect a poorly written manuscript to be accepted for publication. The recent canvass of the members, the results of which were reported in the February issue of the JOURNAL, revealed a justifiable pride in the generally high quality of the papers published by the Society. Through the volunteer efforts of the Publication Committee, a sincere effort is being put forth to maintain that position and even to improve it if possible. It is truly gratifying that most authors show a splendid spirit of cooperation in working with the Publication Committee in putting their manuscripts in the best form. This task of Author, Committee, and Editor will be greatly simplified if each author will use care and judgment in presenting his paper in concise form. Regrettably, there is now and then a manuscript which shows clear evidence of haste, at the sacrifice of clarity in presentation and accuracy in statement. Each author should try to be as critical of his own paper as if he were in the position of a reviewer.

A carelessly written manuscript brings only extra work to everyone and no credit to anyone, so make yours a thing of pride and of as high professional quality as you can. It will then go through the reviewing cycle with the greatest of ease.

A Chemist Views the Atomic Energy Problem*

*F. H. Spedding***

The invention and use of the atomic bomb had such a dramatic effect on the war that it sharply focused world attention on the fact that science had harnessed a new form of energy for the use of mankind. It is obvious from past history that such a discovery will have profound effects on the development of our future civilization. To realize this, one has only to recall the great changes in civilization which followed the harnessing of fire, gunpowder, steam, electricity, and the chemical explosions of the internal combustion engine.

The harnessing of fire brought us out of the state of savagery; gunpowder and similar explosives, such as dynamite, overturned the feudal system, revolutionized warfare and the peacetime practices of mining and building construction. The harnessing of steam brought about the industrial revolution and made the economy of the slave state obsolete. The discovery of electricity literally took us out of the dark ages, annihilated space by giving us almost instant communication with any part of the world, and resulted in the thousands of inventions which are so essential to our modern civilized state. To mention only a few, one might enumerate the electric motor, the dynamo, the radio, photoelectric cell, telephone, television, and radar. The invention of the internal combustion engine made possible the automobile and the airplane. The rapid transportation of people to any part of the world has made isolationism obsolete.

F. H. SPEDDING

The period of incubation between the time of the discovery of each of these

* Speech delivered at the convention luncheon of The Electrochemical Society, New York City, October 15, 1948.

** Director, Ames Laboratory and Institute for Atomic Research, Iowa State College, Ames, Iowa.

forces and the time when mankind has harnessed it for useful application to everyday living has rapidly diminished as our civilization became better organized, so that while the development of the harnessing of fire took place over thousands of years, the harnessing of atomic power should be expected to take place in a few decades.

All of the natural forces which mankind has harnessed have been applied to destructive uses and have profoundly influenced warfare. The far-reaching peacetime effects, as well as to some extent the wartime applications, have resulted in making certain types of civilizations obsolete, such as our tribal societies, our city states, and our small principalities. I believe, however, all will agree that this destructive use of these forces is minor in its ultimate impact on civilization compared to the effect of the peacetime developments which took place in an orderly manner over a period of time. I feel, therefore, that it is unfortunate that the first application of atomic energy to enter the average man's consciousness is a destructive application, since I am convinced that here, also, peacetime applications will, in the long run, so far outstrip the destructive applications that the latter will be minor.

I also feel that it is unfortunate that the average man, due to the great destructiveness of the atomic bomb, has come to look upon atomic energy as a mysterious thing, a sort of black magic beyond his comprehension. Actually atomic energy is no more difficult for the average man to comprehend than is the electric motor, the steam engine, or the automobile. I feel that he can get a very excellent idea of what atomic energy is, and how it may be applied to certain problems, without having to know all the intricate and complicated details which are difficult to grasp. The average man doesn't understand all the principles of how an automobile operates nor could he build one, but he does have a general idea of how it works and he does not feel that there is anything very mysterious about it. I think his general reaction is that the machine is complicated but that he could master it if he wished to devote the time to study the details. He does not feel this is necessary, however, to take advantage of the benefits which he can obtain by owning and using an automobile. In a few years I believe the average man will feel the same way about atomic energy.

The great fundamental discoveries which led to the harnessing of electricity occurred about the beginning of the nineteenth century and during the next fifty years this fundamental knowledge was expanded and developed so that electricity became a very powerful tool in many lines of research, but it was not until the latter part of that century that widespread industrial uses began to be evident, and it was not until this century that electricity really came into its own.

In the case of atomic energy this time-element will be greatly shortened, but it cannot be completely eliminated since even in our highly industrialized era it takes time to develop applications and to make the new discoveries necessary to make such applications. I expect that for the next twenty years the principal use of atomic energy, except for the bomb, will be in the fields of research where it will be used as a very powerful tool which will stimulate many other lines of inquiry and, by an indirect method, help to develop many new industries. I do not look for the general industrial applications, such as its use for power, to occur generally before twenty years have passed.

It is true that during this period we may develop some nuclear engines for experimental or military purposes, but power obtained in this way will be expensive and will have to be subsidized. It will probably be half a century before atomic energy really comes into its own and is put to work on a scale comparable with electricity as it is used at the present time.

The early pioneers in the field of electricity almost certainly had no conception of the many uses to which we have put this force at the present time. It is true they could envision it as a research tool and perhaps could dimly perceive it as a source of light, heat, and power, but I am sure that no one of them could conceive the discoveries which have now been made such as the telephone, television, radio, photoelectric cells, and such. So it is today with atomic energy. We can visualize the use of atomic energy as a research tool, as a source of power, and in a number of other applications, but I am convinced that the really great applications which it is bound to bring about have not yet been envisioned.

Today I am going to try to point out to you some of the developments which I think will ensue in the next few years, particularly as they apply to chemists,

but I want to emphasize that this is just one chemist's look into the crystal ball and I can assure you that looking into the future is a much more difficult task than reviewing the past. Unfortunately the invention of the atomic bomb has put the subject of atomic energy into world politics so that this branch of science has had to be cloaked with a certain amount of secrecy and this makes it difficult to give to you today the type of information which I am sure you would all like to get.

I have given a good deal of thought to the subject of "just what is our atomic secret?". You all know, of course, it is not a formula which can be readily purloined by a secret agent to be turned over to an enemy. Actually, almost all the fundamental principles and basic knowledge which is needed to understand the operation of an atomic bomb or an atomic power engine was known before the war by scientists of all nations and had been published in the scientific journals of these nations and is, therefore, available to anyone who has sufficient scientific background to pursue the subject and who cares to take the time to do so. Therefore, the real secret of how to produce an atomic bomb or an industrial power plant lies in the extensive scientific and industrial know-how which our scientists and engineers possess as part of their heritage and education.

The real secret is not in *how* the bomb or power plant operates, but in how to carry these operations out on a large scale so as to make them effective. Every boy who has had high school physics knows the principles of the electric generator but this is a long way from being able to manufacture a 50,000 kilowatt generator such as is used at Niagara Falls. Here the real secret is in the technical know-how of how to produce this generator and this secret is spread among many individuals in many professions such as miners, metallurgists, electrical engineers, chemists, physicists, etc., and no single man, if he wished, could give away the entire secret. So it is, to a much greater extent, with the so-called secret of the atomic bomb.

You all know that new scientific discoveries or inventions are not the results of "flashes of genius" where the discovery or invention springs full-grown from a void, but are almost invariably the results of methodically building upon and extending the work of others and that the real brilliance occurs when a scientist or engineer perceives a new way to extend or twist the data so as to get the results desired. This process is greatly accelerated when the men working on the problems can get the benefits of talking over their work with other people interested in these fields and the best ideas frequently result from the clash of ideas on ideas.

The compartmentizing of scientific knowledge tends to sterilize science because it tends to cut down the cross-fertilization of ideas which is necessary to its healthy growth and, therefore, I think this country is in serious danger, from the national safety angle alone, of losing its lead in the scientific world due to the emotional approach to the question of secrecy which is so prevalent in certain quarters of our society. I am convinced that if we were certain that the next war was more than 25 years away, by far the smartest move that could be made in the interest of our national safety would be to make *all* information concerning atomic work completely free. I am sure that if the Germans had had complete details of our airplanes and cannons of 1917 in the beginning of World War II that they would not have been of much use. I feel confident that our scientists and engineers, if unhampered, can keep well ahead of those of any other nation.

On the other hand, in the present world situation we cannot be sure that the next war *is* 25 years away, so it is necessary for our national safety that we do retain certain atomic secrets until an international order is set up which can police the world. There is no question in my mind that military matters, the design of weapons, and the design of larger scale production plants should be kept secret until a workable international control scheme has been put into effect, but what should be made public should be left to the scientific and technical people and not be determined as the result of emotional ignorance.

I feel that we are in real danger of losing our world leadership in science and engineering if so much secrecy is placed upon these subjects as to seriously hamper our future progress in these fields, and this hindrance can result just as much from an indirect pressure as from a direct one. For example, if scientists and engineers are frightened into remaining silent about those phases of the subjects which are not real secrets—by witch hunts or by public pressure stemming from ignorance—then these phases

will lag and, in the long run, this will do serious harm to our country.

The Atomic Energy Commissioners have taken an enlightened position in regard to this subject, but are frequently hampered in their efforts to do what they consider would be best for our national long-range safety, by well-intentioned but ill-informed political and public groups. Anything you can do to educate these groups would greatly strengthen the hands of the Commission in this direction.

I, unfortunately, do not know the individual scientific background of the people gathered here today. Some of you, I am sure, know as much or more about the subject of atomic energy as I do. However, I am sure there are a number of people here whose interests have been in other directions and who know very little about the subject, so if some of the things I say sound too elementary to the members of the first group, I hope they will bear with me while I paint in the background which those in the second group will need if they are to understand the subject. Due to the restrictions of secrecy I will have to be rather general in my talk and paint a rather sketchy picture, confining myself to information which has already been declassified or which could be deduced by any expert in the field from information already published in the world literature. I am sure that much more detailed information can be made available to you in those phases in which you are particularly interested, if you will make inquiries through the office of the Atomic Energy Commission.

The basic principles involved in the release of atomic energy are extremely simple. If we wish to release atomic energy either in a bomb or an atomic power reactor, we set up a chain reaction. This essentially means that we start a reaction going where each time an atom reacts it gives off products which cause more atoms to react, and they in turn cause still others to react until the reaction builds up to whatever size is desired. Fortunately for the world, it is extremely probable that the ordinary materials which go to make up the earth are the ashes of former atomic reactions, so that the probability of getting an uncontrolled atomic reaction going in the world is practically negligible. However, just as it is possible in combing the ashes of a previous fire to rake out a few coals or clinkers and start a new fire, so it is possible to rake out a few special atoms and by collecting them to get an atomic chain reaction going.

Ordinary uranium as found in nature consists of mixtures of various isotopes of uranium. These are atoms which behave alike chemically but whose nuclei are constructed differently and, therefore, have different weights. One of these isotopes, U^{235}, has the property that if a neutron comes close to the nucleus it captures the neutron and forms uranium isotope U^{236}. This isotope or atom is unstable and in a very short time, in the order of millionths of a second, will explode or fission into two atoms of intermediate atomic weight such as barium and krypton and give off two or more neutrons. These neutrons if they go close to other U^{235} nuclei will cause them in turn to explode so that we see that, if we gather together U^{235} atoms, it is possible to get a chain reaction going in them. Therefore, if we separate out the pure 235 isotopes of uranium we have the necessary raw material for an atomic bomb.

The principle involved here follows the same rules that you have in the breeding of rabbits. The first generation of rabbits produces many offspring and they, in turn, produce more rabbits and if the rabbits are tended carefully so that they do not die off, you can build up to a biological explosion. On the other hand, if you have hawks to eat the rabbits or if you keep the rabbits separated from each other, then you will destroy the chain and the breeding of rabbits dies out. So it is with the atomic reactions. Most atoms capture neutrons or act as hawks and remove the neutrons from the chain reaction.

When an ordinary atom captures a neutron it usually produces a radioactive substance but it does not fission. Some of the atoms, such as cadmium and boron, are very efficient in capturing neutrons so they act as poisons in a chain reaction and very small amounts of them tend to stop the reaction. Therefore, in producing raw materials for a chain reaction it is necessary that these materials be absent and the raw materials have to be especially pure in regard to these elements. On the other hand, these same elements, if put in rods which can be pulled in or out of the reacting material at will, make fine control mechanisms for controlling the atomic reaction, for it is by this means that it is possible to control the number of atoms reacting in each generation so that a given reactor can maintain a constant

rate of production of power, or increase or decrease it at will.

The 238 isotope of uranium also captures neutrons but the resultant nuclei do not fission but rather become radioactive and slowly decay by radioactive process to new chemical atoms such as plutonium. The plutonium in turn can fission but the rate-controlling step is the rate of production of plutonium 239 through U^{239}, and therefore uranium 238 in a chain reaction acts as a poison until it becomes plutonium. For this reason, pure natural uranium metal cannot sustain a chain reaction under ordinary conditions.

In a moment I shall point out that under very special conditions not likely to occur in nature, a chain reaction can be made to take place with normal uranium, but I can reassure you that the probability of any of our natural deposits of uranium becoming chain reactors is insignificant.

We see, therefore, that all that is necessary to snuff a chain reaction is to have less neutrons acting with U^{235} in the second generation than react with them in the first generation. I pointed out a moment ago that this could be brought about by having other atoms present which tend to capture them. It can also be brought about by having the geometry of the surrounding mass such that a large percentage of the neutrons escape from the neighborhood of the U^{235} atoms. Thus if you take a thin sheet of U^{235} uranium metal so many of the neutrons will escape out either side that there will not be enough remaining with the uranium to build up the chain. The metal in this form is then said to be sub-critical. However, if I wad the sheet up into a ball, the number escaping to the number being captured will be a function of the diameter of the ball and when the ball reaches a certain size it is said to become critical and in all masses of uranium 235 above these dimensions an explosion will ensue.

Therefore, you see that the mechanism of setting off an atomic bomb is extremely simple. You have two subcritical masses of uranium 235 which when kept apart are perfectly stable like ordinary uranium and will not explode. However, if you bring them together the mass becomes critical and it takes off.

This may sound as if I have given you the secret of the atomic bomb, but such is not the case because under ordinary circumstances as the reaction takes off it heats up the metal, vaporizes it, and blows itself out so that as far as an atomic explosion is concerned the result is a fizzle, even though it may be very unhealthy for anyone in the immediate neighborhood. How to make one of these reactions take off with full force is one of our secrets.

The power-pile is equally simple in its naive conception. It is found that if you take a pile of graphite and interlace it at certain intervals with rods of uranium metal that it is possible to get a chain reaction going, providing the materials are pure enough and the pile is big enough. The uranium 235 atoms are embedded in the metallic uranium and if they are spread throughout the graphite pile at the right distances more U^{235} atoms will capture neutrons in the second generation than the first and a chain reaction is set up. The neutrons that are given off by the U^{235} come off with very high energy which the U^{235} atoms do not capture readily. The graphite which is called the moderator acts as a means of slowing them down so that they can be captured. Heavy water can also do this as can other substances.

In order to control the piles, control rods are placed within the pile. These might be strips of cadmium metal or solutions of boron and by controlling, from the outside, how much cadmium or boron is in the pile, it is easily possible to control the operation of the pile to any energy desired—say one watt, one kilowatt, or a million kilowatts, or at whatever energy you have nerve enough to run the pile. It should be recalled, however, that unless you remove the heat as fast or faster than it is formed, it will build up to a thermal explosion. Therefore, for high energy piles it is necessary to have a coolant going through the pile so that the energy can be removed and taken outside where it can be usefully employed in producing steam or electricity.

A few moments ago I mentioned that when uranium fissions it gives off two lighter, radioactive atoms such as barium and krypton, and that even the ordinary atoms become radioactive from capturing neutrons. Therefore, when the pile is operating, it gives off enormous amounts of radioactivity such as gamma or x-rays, neutrons, beta particles or electrons, and these are very deadly to anyone in the neighborhood. For this reason it is necessary to surround the pile with material of great thickness to

act as shields and to cut down the amount of radiation escaping.

At this point I might summarize for you some of the chemical problems associated with the design of a power pile. For obvious reasons of security, I cannot give you any details in a talk such as this as to how far we have progressed in these problems, but I can pull together the various types of chemical problems which I am sure many of you could think up yourselves, if you gave thought to the matter, which have to be solved if a successful power-pile is to be built.

First consider the fuel rods. Thorium and uranium are the known fissionable materials generally available, but a great many problems arise as to how to fabricate these. What shape should they be? How do you produce them in quantity in the desired shape? How pure should they be? How do you produce the material of required purity? Should they be pure metal or alloys, and if alloys, which alloys?

It should be pointed out that the nuclear properties in regard to neutrons determine which alloys can be used as well as the chemical properties of the metals employed. This frequently means that metals which have heretofore been commercially rare may be in demand and the electrochemical industries may play an important role in producing good metal of these lesser known elements in high purity. Further, these fuel rods have to be cooled if very much heat is to be taken out and the problem of corrosion enters.

Some alloys will take higher temperatures or withstand corrosion much better than others and the choice of which one to use in a given reactor design depends to a great extent on our knowledge of how these alloys behave under the conditions required in the design of the reactor. Also, I might mention that the fuel rods do not necessarily have to be metal, but may be refractories which have good heat conducting properties, or maybe even liquids.

I might also mention that stainless types of alloys would be very desirable or that in some cases it is necessary to encase these materials in cans or coated metals which also possess good heat conducting properties. Here again the electrochemical industries can play a major role. The fuel rods may be enriched with fissionable atoms such as U^{235} or plutonium 239 and the more the enrichment the smaller the design of the reactor. Further, as the fuel rods react the uranium in fission produces other metals and atoms which tend to progressively change the property of the alloys present and some of these may maintain their physical strengths for far longer times than others.

The coolants can be of many types. They might be air, rare gases, metal alloys, organic liquids, and it must be remembered that the nuclear properties of the atoms being used must be desirable. These coolants must be capable of transporting the heat generated, and they must not be corrosive to the elements of the pile. Here again, materials which have been slightly too expensive to take hold commercially may here become important through their nuclear properties, and new industries for producing them may develop.

The moderators can be of various types, such as graphite, heavy water, beryllium, or other light atoms; they also must withstand temperatures, radiation, and corrosion.

Finally, the shields must be able to withstand all these reactions. Further, as the pile gets larger its weight increases and the thinner we can make the shields the more feasible it becomes to put a reactor in an airplane or a ship. It is all very well to use a thick wall of concrete, but the shields of the future undoubtedly will contain many new types of alloys and ceramic materials which will permit them to be much thinner than the ones now in use.

The control rods can be made of various substances and here again new metals, alloys, and ceramic materials with special properties of being able to withstand radiation, corrosion, and high temperatures will be in great demand.

The pile also has to be monitored for the level of radiation with regard to neutrons, electrons, and gamma particles, and these new materials of very high purity will again be in demand for producing the instruments of the future for the control of these operations.

If the piles are to operate as power-piles, the fuel rods will have to be removed from time to time and purified in regard to activity of neutron poisons and placed back in the piles. This means the construction of chemical equipment which can operate simply by remote control and which will withstand radiation, corrosion, and heat. Here again the electrochemists can play an important role in producing this equipment and giving it surfaces which will with-

stand the reactions and even in helping devise remote control processes for carrying out these operations.

I should like to point out at this time that as new processes are developed for producing new alloys, new ceramic materials, and unusual metals of very high purity, these same processes can be used for producing other materials for industry in general. The very pure materials themselves will find many industrial applications which probably in the long run will far outweigh their use in nuclear reactors.

I believe it is obvious from what I have just been saying that, as various types of power-reactors are developed in the future, greater and greater use is going to be made of elements of the periodic table which are not generally available commercially in quantity and in the forms desired. These elements will be demanded in the construction due to their peculiar nuclear or chemical or physical properties. Many of them are reasonably abundant in nature but, due to lack of commercial demand, have never been studied systematically for the purpose of producing them cheaply, in quantity, or with great purity. Those which are available are usually available as the result of by-products of other processes.

As these lesser known elements are demanded in various metals, alloys, and compounds, new industrial processes will have to be developed to produce them, starting all the way from the concentration of the ores, through the refining, right up to the fabrication of the finished product in the desired form. I feel confident that the electrochemical industry will play a very important part in the development of these processes and that the industries which do develop them will find that in addition to the Government's demand for reactor materials, these substances will find wide industrial application in other lines of endeavor.

So far today I have said very little about tracers, since I assume that all of you are familiar with them and could, if you wished, give thousands of illustrations of how this powerful new tool could be used in the scientific investigations which are being carried out in your various fields. It is, of course, obvious that the tracer technique will be widely used by all branches of chemistry and metallurgy, and that its use will greatly speed up the solving of the many problems in these fields. The tool is, of course, ideally suited for subjects of corrosion, erosion, analytical chemistry, research into mechanisms, rate and equilibrium problems, etc. I believe these techniques should be particularly useful in devising methods for producing purer and better products and in determining the purity of these products.

The Ames Laboratory of the Atomic Energy Commission, of which I am the Director, has devoted a considerable part of its effort to the pioneering type of research where these new materials are tried and has produced a considerable number of special types of metals, alloys, and chemicals of extremely high purity to see whether these new materials are useful for reactor development.

As an example of this type of development, I might mention the rare earths. As you know, these elements are not really rare in nature but are called the rare earths (1) because they occur widely scattered throughout matter, generally in low concentrations, and (2) because of the extreme difficulty in separating them from each other. The older fractional crystallization methods of separating them required years of labor to produce nominal quantities and few chemists had the patience, interest, or drive to do this. Therefore, the literature concerning the properties of the metals and alloys of these compounds is limited. However, as mentioned previously, when uranium fissions it produces two radioactive atoms of lighter atomic weight.

This break may occur in many ways so that in a bar of uranium which has been ten per cent fissioned, you will find some forty elements present among which rather prominently occur various members of the rare earths. Some of these have very bad neutron properties, so it became desirable to obtain the rare earth metals and compounds in pure form to study their nuclear properties. As reactors are built it will be necessary to remove some of the rare earths from the pure materials, and it will be desirable to see what the effects on structure of various percentages of rare earths are in the fuel material. Therefore, it was necessary to obtain these materials for experimental studies.

The Ames Laboratory developed a process involving adsorption columns, on the water-softening principle, where the separation of these rare earths could be greatly speeded up, and we have succeeded in producing a number of very pure compounds of these elements. We have also produced the pure metals of a

number of them [Ce, La, Nd, Pr, Y, Th, and Be].

I believe from what I have said today it will be evident that it is possible to design reactors in many ways and that the problem of design in each of these reactors requires the combined efforts and knowledge of almost all kinds of scientists and engineers. Basic discoveries in all the fields of physical chemistry, metallurgy, and engineering will have to be drawn upon to make the practical applications, and almost any scientific fact in these fields might prove useful in the practical applications of atomic energy.

Here again, I think it points up the fact that this country, for its own national security and safety, will have to draw a very careful line as to where secrecy does our own country more harm than it could possibly do good by withholding information from a potential enemy. One might say that the telephone book or publications such as "The American Men of Science" or "Who's Who" would prove very useful to the enemy in that it would enable them to quickly locate our key scientists and engineers. On the other hand, I don't believe anyone would take the position that these books should be stamped "Secret." It is obvious that the usefulness of these volumes in their unrestricted category far outweighs any good which could be achieved by withholding them from the enemy. The same is true of all the fundamental branches of science, and I think it is very important that we all give a strong support to the Atomic Energy Commission in its effort to free large areas of scientific investigation. It is evident that we are taking a calculated risk in doing this, in that someone in one of these fields might discover a fact that would be of great benefit to a potential enemy, but I feel that any harm resulting from this calculated risk is insignificant compared to the impetus which a free science in these fields would give to our scientific development.

I believe that we can depend on the patriotism of our scientists, and the editors of our journals, to see to it, that in most any case where such a leak might occur, that this information would be withheld. Of course by this I do not mean that everything should be made public. There are certain fields such as weapon design, production processes, etc., where in the troubled world situation it would be desirable to have all information examined before it is released, but I think these fields should be strictly limited and great care should be taken that we do not let unintelligent secrecy destroy the processes by which our industry and science have become great.

In closing, I believe a chemist is allowed one wild dream in making his predictions and in doing this I would like to point out the very intriguing possibility of converting the nuclear energy directly into electricity. All the present proposed applications of converting nuclear energy into useful energy go through the process of fission producing heat and then generating electricity and, of course, as you all know we are limited by the thermodynamic efficiency. If a process could be found to take electricity directly from the pile, as we now take electricity directly from chemical reactions, then a great milestone would have been passed in science's march of progress.

Plan now to attend

The 95th Meeting of The Electrochemical Society

at the Benjamin Franklin Hotel in Philadelphia
May 4, 5, 6, and 7, 1949

Sessions on
Luminescence, Rare Metals, and Theoretical Electochemistry

The Importance of the Unpredictable

In his Acheson Medal address, Dr. Duncan A. MacInnes urged that research institutions and industrial laboratories devote a larger proportion of effort to long range fundamental research having no predictable applications. Pointing out that the processes of living tissues intimately involve electrochemistry, he suggested that researches should seek to comprehend more fully the behavior of substances in solution and that "the physical chemist should be looking for new procedures, as well as examining the theoretical foundations and improving the precision of the established methods."

The Society in recent years has not given sufficient attention to the promotion of basic research. Twelve years have elapsed since a symposium was devoted to the more fundamental aspects of electrochemistry. At the Philadelphia meeting of 1937, Dr. MacInnes, then president of the Society, arranged a stimulating and most successful program on "Electrochemical Methods in Biology." Ideas presented at that time have influenced in no small way the subsequent course of biochemical and medical experimentation.

It is true that the various divisions of the Society do present from time to time valuable theoretical papers pertaining to their fields of specialization, but these papers are usually accounts of research having predictable and practical applications. Very rarely are these reports of researches undertaken purely for the satisfaction of intellectual curiosity, and very seldom do they have broad significance or implication.

The interesting symposium of the General and Theoretical Division being arranged by Professor Glockler for the coming Philadelphia meeting fortunately constitutes a revival of effort in the support of basic knowledge. This program will include papers dealing with a wide range of scientific work and should attract a large attendance and participation.

Symposia on fundamentals should become a regular feature of the Society's spring meetings. Contributions to our knowledge of electrode reactions, overvoltage, passivity, oxidation and reduction kinetics, the processes of conductance in structures as diversified as nerve fibers, semi-permeable membranes and solid semi-conductors should have important and unpredictable consequences in broad areas of science, technology and human affairs.

R. M. B.

Current Affairs

More Plans for Philadelphia Convention

Excellent progress is being made on the schedule of events for the Philadelphia Convention, both technical and social, according to reports from the Convention Committee.

Heading this committee is Ernest G. Enck, General Chairman, and the following sub-committee chairmen: Harry A. Alsentzer, Entertainment; Milton B. Barba, Plant Visits; Russell P. Heuer, Hotel Reservations; John F. Gall, Meeting Accommodations; Edgar L. Eckfeldt, Registration; Hiram S. Lukens, Finance; Albert A. Ware, Publicity. Working with them are the officers of the Philadelphia Section: R. H. Cherry, Chairman; J. L. Crenshaw, Vice-Chairman; J. F. Hazel, Secretary; Arthur Osol, Treasurer.

The dates for the Philadelphia meeting are May 4, 5, 6, and 7, 1949.

Headquarters for the Convention is the Benjamin Franklin Hotel, 9th and Chestnut Streets, Philadelphia. The hotel is equipped to provide adequate facilities for all the different sessions of the Convention. Advance reservations should be made direct to the hotel, and reservation cards will be mailed to the membership in ample time.

Technical Sessions

The technical sessions consist of symposia on the subjects of Theoretical Electrochemistry, Luminescence, and Rare Metals. There is every indication that each of these subjects will be handled by leaders in their respective fields. The exact program for each of the symposia will be published as soon as it is completed.

The symposium on Theoretical Electrochemistry, headed by Chairman George Glockler of the University of Iowa, is an important feature of the meeting and will include papers by such authorities as Professor V. K. La Mer of Columbia University, Dr. H. A. Abramson of the College of Physicians and Surgeons, Dr. Karl Solinger of the U. S. Public Health Service, Professor K. G. Stern of Brooklyn Polytechnic Institute, Dr. J. L. Oncley of Harvard Medical School, Dr. H. A. Laitinen of the University of Illinois, Professor Glockler and Dr. J. W. Sausville of the State University of Iowa, and others of like caliber.

The Symposia on Rare Metals and Luminescence is being sponsored by the Electronics Division. A gratifying response to these symposia has also resulted in papers from outstanding experts in these fields, both foreign and from our own country. The JOURNAL will publish a list of these papers, with the authors, as the program rounds out.

Ladies Program

Plans for an attractive program of events for the ladies attending the Philadelphia Convention are developing satisfactorily, according to Dr. Harry Alsentzer, Chairman of the Entertainment Committee. He has organized a ladies' committee to arrange this part of the entertainment.

At present the schedule calls for a "get acquainted" gathering on Thursday morning, May 5th, then a special luncheon for the ladies, to be followed by a trip to a number of points of interest in Philadelphia and vicinity. On Thursday evening, the ladies of course will attend the President's Reception and Dinner.

On Friday, there will be a luncheon for the ladies at one of the historic colonial hostelries near Philadelphia, to be followed by a visit to the famous Du Pont Gardens at "Longwood."

The Entertainment Committee is making every effort to see that this program will be most enjoyable, and further details will be published in the JOURNAL as they are completed.

Round Table Discussions

The Industrial Electrolytic Division of the Society is planning a round table discussion for the Philadelphia Convention on "Materials of Construction for Chlor-Alkali Plants."

The subject will be approached from two directions, i.e., (1) from the standpoint of requirements of various processes, and (2) from the standpoint of the properties of various processes.

Chlor-alkali producers and equipment suppliers will have the opportunity of drawing upon the experience of many

experts in the field for the discussion of their problems.

Since time is short and the scope of the round table unlimited, it would be helpful in the preparation of a rough outline to have suggestions or contributions of special interest communicated, in advance of the meeting, to the Secretary of the Division: M. S. Kircher, Hooker Electrochemical Company, Niagara Falls, New York.

The Electrothermic Division is fortunate in securing the services of Mr. N. E. Promisel, Navy Department, Bureau of Aeronautics, to act as leader or moderator for the round-table discussion on "Special Melting Techniques for Metals," to be held at the forthcoming National Spring Meeting in Philadelphia. Announcements of the panel members for this round-table discussion will be published in subsequent issues of the JOURNAL of the Electrochemical Society.

This special meeting will be held in conjunction with the symposium on "Rare Metals," sponsored by the Electronics Division, and the committee anticipates considerable participation.

Plant Trips

It is planned to devote part of the time allotted to plant trips to a visit to one of the leading chemical plants in the vicinity of Philadelphia. Other plans to be announced.

Spotless Electroplating Laboratory at Westinghouse

A new electroplating laboratory of the Westinghouse Electric Corporation features the neatness and efficiency of a well-designed kitchen. The lab—used to develop better electroplating processes for nickel, copper, chrome, silver, gold, and other metals—features acid-resisting tile walls and floor, sound proofed ceiling, tempered Carrara glass table tops and completely concealed plumbing. In addition to the chemical laboratory shown here, there also is included an office and meeting room, workshop, storage rooms, and a pilot line production room. New electroplating processes leaving the laboratory are ready for initial application in commercial production. The Laboratory shown is at the company's plant in Pittsburgh.

Diamond Alkali Opens Houston Works

The nation's newest plant for the electrolytic production of chlorine and caustic soda, one of the largest of its kind, was recently put into production when the Diamond Alkali Company opened its Houston Works. The new plant which cost $14,500,000 occupies a 325-acre tract along the Houston Ship Canal 25 miles from Houston. Construction was begun in the summer of 1946 and the capacity of the completed plant is 220 tons of liquid chlorine and 240 tons of caustic soda per day. The plant designed by Diamond engineers was built by Brown & Root, Inc. of Houston.

The Electrochemical Society, of which Diamond Alkali has been a sustaining member since 1942, was represented at the dedication ceremonies by Mr. Karl E. Luger who reported most favorably on the varied activities of the day. These included a morning session of six technical papers dealing with the novel features of the installation. Luncheon was followed by a tour of the plant. The formal dedication included an address by Dr. T. S. Painter, President of the University of Texas, on the interrelation of industry and higher education. He dealt at length with the value to industry of the basic research done by the universities. The day's activities were concluded with a Texas barbecue dinner complete with all the trimmings which, according to our representative, left everyone pleased that Diamond had moved to Texas.

The decision to locate the new plant in the Houston area was influenced by many factors chief among which were the growing chemical industry of the southwest, which meant large existing markets for the output of the plant, the ready availability of usable raw materials, natural gas, cooling water and transportation facilities. The new plant is very largely self sufficient. The basic raw material is salt brought by pipeline from wells 17 miles away. All the electric power and steam required are generated on the spot using natural gas as the basic energy source. The Houston Ship Canal provides both transportation and cooling water. A large part of the liquid chlorine produced is delivered by pipeline to a nearby customer.

With the relatively high year-round temperatures that prevail in the Gulf Coast area, it was considered feasible to install about 60 per cent of the equipment out-of-doors, thus realizing a very considerable saving in building cost. Typical of the outdoor installations are the steam generating units, the caustic evaporation equipment and the facilities for brine treatment. The production units consist of the power plant, pumping stations, brine reservoirs, brine treating equipment, the electrolytic cells, caustic evaporation units, solid caustic plant, and the chlorine liquefaction and loading facilities. In addition to these are the brine wells and pipelines for transportation of brine and water to the plant and of liquid chlorine to its ultimate consumer.

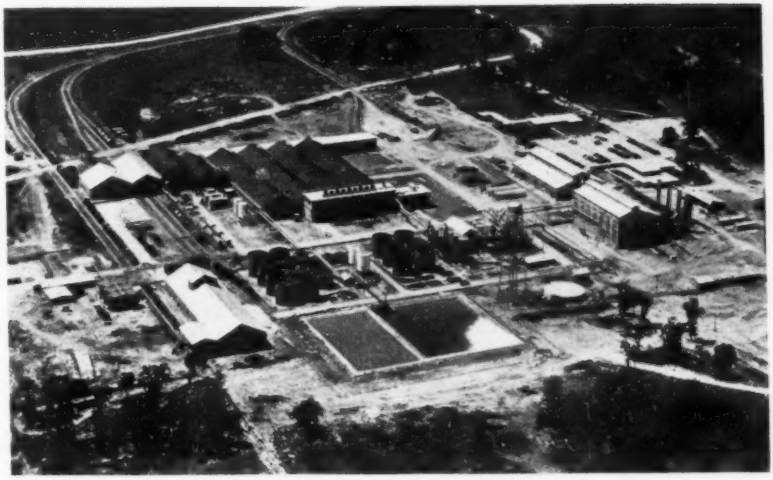
Service facilities consist of: the Administration Center, completely air-conditioned, providing offices for management, accounting, purchasing, traffic and engineering; the Personnel Building, with central locker rooms, washrooms, first aid dispensary and offices for personnel and plant protection forces; and the Shop and Stores Building, complete with a well-equipped machine shop, tool room, and storeroom.

Plant personnel totals 200; of this number 40 are technical and administrative employees and 60 are on direct operation. Maintenance, repair and labor are handled by 100 workers. Ninety-five per cent of the employees are native Texans.

Brine Production and Treatment

The supply of salt, essential raw material from which chlorine and caustic soda are derived, is located at a salt dome at Barber's Hill 17 miles from the plant. Here 400,000 gallons of fresh water per day are pumped into the dome from one of two wells, dissolving the salt and returning the brine to the surface. The brine is pumped into a reservior of 1,000,000 gallons capacity at the well site and then carried through cast iron pipelines to a 650,000 gallon open storage reservior at the Houston Works. Nearly 2,000 tons of brine a day are brought from the salt wells to the plant.

The 17 mile brine line runs under rivers, across swamps and beneath the Houston Ship Channel before reaching the Diamond plant. Its construction provided several interesting sidelights. For instance, flat-bottomed skiffs (mud boats) powered by motors mounted with



Air view of Diamond Alkali Company's new plant near Houston, Texas

airplane propellers were necessary to lay the line in one old lake bed which even at high tide contained only one foot of water above its 12-foot depth of mud.

From the storage reservior raw brine is pumped to the brine treatment system (hot process) to free the solution of impurities (calcium, iron, aluminum, magnesium) prior to its electrolytic decomposition into chlorine, sodium hydroxide, and hydrogen.

The raw brine is treated with sodium carbonate obtained by reacting brine containing a small percentage of caustic soda with flue gas from the boilers. Removal of impurities from the solution is essential to prevent their deposition on the asbestos paper diaphragms of the cells used for subsequent electrolysis of the brine, a condition which, if tolerated, would quickly impair cell operation by clogging.

Filtering of purified brine in anthrafilt pressure filters completes the preparation of the solution for electrolytic decomposition of its salt content. These filters are totally enclosed tanks, 78" in diameter and 5 feet high. There are five of them, permitting any one unit to be back-washed whenever needed without interrupting the processing cycle.

Use of the so-called "hot process" in place of the conventional "cold" method of brine treatment is regarded by Diamond engineers as a refinement of considerable importance in chlorine-caustic soda production technique. Reaction time is shortened, less space is needed to house required equipment, and effectiveness and uniformity of impurity removal are increased.

Treated-and-filtered brine is pumped into one of eight storage tanks, which provide a capacity of 1,500,000 gallons. Treated brine is drawn through a two-pass preheater for heating to 160° F. before resaturation in a 50,000 gallon tank to which salt slurry recovered from caustic evaporation is added. This slurry is recycled continuously. Passage of the brine through it promotes maximum salt concentration which, in turn, contributes to longer life of the anode in the electrolytic cell.

Chlorine Production

The electrolytic cells embody improvements in design worked out by Diamond's Research and Development Staff over the past 10 years. The cells are rectangular and employ a submerged asbestos paper diaphragm instead of a deposited diaphragm; the cells operate at 10,000 amperes and at average current and power efficiencies normally obtained from diaphragm cells.

Glass—thousands of feet of it—is used

for entrance headers and chlorine exit piping because of its light weight, economy, and transparency. For caustic, glass also makes possible better joining of lengths in comparison to standard lead bends employed for ceramic stoneware joints. Chlorine gas is piped to cooling and liquefaction equipment. Some 2,000,000 cu. ft. of hydrogen are produced daily and uses are being sought to consume this supply. However, a small portion of the gas is collected and diverted to compressors for producing hydrochloric acid.

Chlorine gas from the cells passes through two enclosed glass coolers—a primary cooler and a secondary cooler—where it is cooled to 105° F. and then to 60°–70° F.

Upon cooling, chlorine gas is passed through three ceramic plate-type surface drying towers and thence through three cast iron drying towers. Next compressed by special rotary compressors equipped with sulphuric acid seals, the gas is "scrubbed" in towers to remove condensable impurities.

Liquefaction of the chlorine is then accomplished by cooling the gas to approximately minus 20° F. in three refrigerating units, incorporating centrifugal compressors, each of which is capable of liquefying 100 tons of chlorine a day. From these machines the liquid chlorine is delivered directly to 30-ton or 55-ton tank cars, or to weigh tanks for delivery by pipeline or for loading into cylinders.

By liquefying chlorine with refrigerating machines rather than by the normal method using reciprocating compressors, a coolant, a refrigerant, and the equipment required to handle these materials, several advantages are secured.

Caustic Soda Production

From the electrolytic cells, the solution of caustic soda and salt (cell liquor) is pumped to a 1,000,000-gallon storage tank farm comprising six tanks. Raised to 180°-190° F. the solution then goes to three sets of evaporators where caustic soda strength is increased and the salt is crystallized out until a product of the desired strength is obtained.

All of the effluent from the cells is evaporated to a solution containing 50 per cent caustic soda. At this concentration, all but a very small fraction of the salt has been removed by crystallization. Upon cooling and filtering, the solution is ready for loading into tank cars as 50 per cent caustic soda.

To produce 73 per cent caustic the evaporation process is continued on a portion of the 50 per cent solution. This higher strength caustic solution is then ready for loading and shipment in tank cars, or for pumping to another unit of the plant for making solid, flake and ground caustic, which are loaded into steel drums for marketing.

The packaging plant, while not yet completed, is scheduled to go into operation in the near future, and will feature automatic and semi-automatic handling to a degree hitherto unapproached in the industry. The conventional method of fusing caustic in direct-fired cast-iron pots as practiced in the industry since its earliest days has been successfully converted to a closed, continuous basis.

Hydrochloric Acid Plant

Diamond's hydrochloric acid plant, rapidly nearing completion, is scheduled to be put into operation soon. Its capacity is 10 tons daily.

After passing through the condensate trap, hydrogen from the cell room is cooled and compressed. Combined with "sniff gas" obtained from chlorine liquefaction, the mixture is burned in a furnace forming hydrochloric acid. The gas obtained is then cooled in a reflux cooler, absorbed in water and stored or shipped as 33 per cent hydrochloric acid.

General Plant Utilities

Diamond generates its own power and has provided a large installation for this purpose. It consists of four boilers, each capable of producing 100,000 lb. of steam per hour at 900 lb. psi pressure and 900° F. for three turbine generators with a total capacity of 30,000 kva. Approximately 14,000,000 cu. ft. of natural gas are used daily to fire the boilers. Turbine-bled steam is used in heating of brine, evaporation of water, and other general plant requirements. Direct current for electrolysis is supplied by a bank of mercury-arc rectifiers.

Sixty million gallons of water for condensing steam and various process cooling requirements are pumped from and returned to the Houston Ship Channel daily without contamination. Three large vertical pumps at the inlet station, each driven by a 300 hp motor, are capable of pumping a total of 45,000 gallons of water per minute from the Channel, two-thirds of a mile away.

New Atom Head

Dr. Kenneth S. Pitzer of the University of California recently became Director of Research of the Atomic Energy Commission, an assignment which is considered the most important scientific job in the world today. Dr. Pitzer succeeds Dr. James Fisk of Harvard.

Under Dr. Pitzer's control will come the chain of laboratories which the Atomic Energy Commission is building throughout the country. Much of the work will be top-secret, concerned with the atom bomb and other nuclear weapons. Also, a part of Dr. Pitzer's responsibility will be to make the atom serve rather than threaten civilization.

Golden Jubilee of Chemists' Club

The Chemists' Club celebrated its 50th anniversary, with a dinner party at the clubhouse, 52 East 41st Street, New York City, on December 9th.

The Chemists' Club was founded in November, 1898, with 154 charter members. Taking a leading part in establishing the Club were Dr. Leo H. Baekeland, Prof. Marston T. Bogert, Prof. Charles F. Chandler, Prof. Morris Loeb, Dr. E. G. Love, Dr. William McMurtie Mr. T. J. Parker, Dr. Charles F. Squibb, and Dr. Maximilian Toch.

From its first meeting and until March, 1911, the headquarters of the Club was at 180 West 55th Street, New York City. A loan of $1,000 by Prof. Chandler together with sizable contributions from many others, made it possible to obtain this first meeting place.

The object of The Chemists' Club was to provide a professional home for American chemists, to develop personal and professional contacts among those interested in chemistry, and to build up a great chemical library.

From the first, the Club grew rapidly and in March, 1911, moved to its present home and today owns the Chemists Building in which it is housed. Active in securing the new and larger quarters was Dr. Morris Loeb, whose great personal efforts contributed so much to the success of the Club. Another factor which did much to build up the Club was the rapid development of the library, which had combined with the library of the American Chemical Society, and later had received the private libraries of many noted scientists.

Now, on the occasion of the 50th anniversary of its founding, The Chemists' Club has realized its early aims. It is the home and the meeting place for scientists from the United States and abroad; it is used for the meetings of the New York Sections of leading chemical societies, and it is a center for the exchange of thought and information among chemists.

Fifty years of the activities of this Club add up to an impressive total of men and achievements.

AIEE Holds Winter Meeting

The Winter General Meeting of the American Institute of Electrical Engineers was held at the Hotel Statler (Pennsylvania) in New York City, January 31st to February 4th.

The technical program for this meeting was the largest in the history of the Institute, comprising the presentation of about 150 papers in 38 sessions. In addition there were some 18 conferences.

The inspection trips were noteworthy for their interest and variety, and included trips to Consolidated Edison Company's Jamaica Substation, Federal Telecommunication Laboratories of the I.T.&T. at Nutley, New Jersey, the Columbia University Cyclotron, and the Material Laboratory, U. S. Navy Yard at Brooklyn, New York.

The social program featured a dinner dance, smoker, theater tickets, and an attractive program for the ladies, highlighted by a trip to the United Nations, a fashion show, and other activities.

Expansion Approved for Carnegie Tech

Carnegie Institute of Technology, Pittsburgh, Pennsylvania, recently has announced the approval of a four million dollar campus building and renovation program.

Carnegie will build a million-dollar wing on to Engineering Hall and will spend over a million dollars on a power plant and a steam and electricity distribution system. The program also calls for extensive revamping and renovation of available space in existing buildings in the colleges of Engineering and Science, Fine Arts, and Margaret Morrison Carnegie College.

Actual work is expected to begin this spring, and the whole building and renovation program is expected to cover approximately a two-year period.

Section News

Chicago Section

The Chicago Section met at the Chicago Engineers' Club on December 3rd. Mr. James Smith, the Chairman, opened the meeting by presenting a biographical sketch of the speaker, Mr. Joseph E. Drapeau Jr., technical director of Metals Refining Company. Mr. Drapeau spoke on "Innovations in the Use of Metals." In the development of the topic, the speaker compared the living standards of the present day and those of the Pilgrim settlers with regard to the production factors which have effected this change. It was pointed out that most of the changes that permit the decrease in working hours and increase in material wealth have been effected by labor-saving devices and methods. Energy machines, interchangeable parts, assembly lines, have all played a part.

The modern process started with the development of Cu flake pigments by Henry Bessemer in England about 1800 and has developed steadily ever since. Today, this method is used in the formation of cutting tools, of high melting alloys, the mass production of precision parts, brushes for electrical contact, bearings for lubrication, metallic brakes, porous filters, paint pigments and fuel additives.

The uses and contributions of aluminum, lead, copper and iron during the last war were discussed in detail. They ranged from the use of Cu O paints to prevent growth of barnacles on the bottom of Navy vessels to the use of metal powders and oxides as a component of incendiary bombs.

The powder metallurgy consists of two fields. The first is, of course, producing metal powders and the second is utilizing them in a commercial product. Several methods used to produce the metal powder are: the disintegration of a brittle form of the metal or oxide, atomization following by chilling of the molten metal, electrolytic deposition and reduction of chemical compounds to free metals.

The formation of an integral metal mass from the metal powder is a field which was given great impetus during the war. The metal particle is fused at its surface to the surface of its neighbors by heat and pressure; one of the great advantages being the lower temperature at which this assembly can be carried out. Other desirable properties are the precision, the porosity, and the light weight of the casting as well as the good strength.

The talk was presented in an interesting and logical manner. A great fund of practical information and creative ideas illustrated the field of powder metallurgy, showing how it developed, how it is used, and how it is likely to be used in the future.

The keen appreciation of the audience, for the future possibility and application to other fields, was evident in the discussion that followed the formal close of the talk.

H. D. Douglas, *Secretary*

Cleveland Section

A well-attended dinner meeting on November 9th was the opening event of the Cleveland Section's 1948-49 series.

Mr. J. H. Winkler, Technical Advisor of Battelle Memorial Institute, was the guest speaker; his subject, "Graphic Arts and Research," was delivered in his own inimitable style.

The speaker outlined the various processes of printing, both color, and black and white, having many samples and exhibits with which to demonstrate his subject.

It was surprising to hear that the printing industry is actually larger than the electrochemical industry, having approximately a four billion dollar a year volume.

Mr. Winkler described the photographic process for printing on textiles, woods, etc. He demonstrated the four color process of printing and described the planographic method. This differs from the more prevalant method of printing, in that there is no difference in the level of the surface of the printing plate. Printing by this method is accomplished by employing variations of wetted surfaces which enables the plate to take up ink in certain areas.

The speaker pointedly mentioned the vinylite mold as being the most significant development in the electrotyping industry. The versatility together with the number of plates which can be made from vinylite have appreciably reduced printing costs.

Regarding research in the printing industry, the speaker thought that "up until very recently the next lowest research expenditure could possibly be found in the stone cutting business." The printing industry being so diversified and having so many small establish-

ments of an extremely individualistic nature makes it virtually impossible to put forth much research effort. This is lately being overcome by many small concerns contributing to research programs conducted at various institutions for their mutual benefit.

A typical result of what research can do is noticeable in a new process being developed at Battelle known as "zerography." This envolves the photo copy method using dry powders fixed to the printing plate material by means of an electrostatic field and employs the phenomena of photo conductivity.

By a rather interesting procedure a printing plate having been exposed photographically to an image, is dusted with a powdered substance. The plate receives variable electrostatic charges depending upon the intensity of light striking its surface. The particles then adhere to the plate in proportion to the variable charge on its surface. The plate is then ready for the usual printing process.

Several other contributions of research to the printing industry were mentioned such as new types of glue used in book binding.

The meeting was adjourned following a discussion period.

The next meeting of the Section, held at the Hotel Cleveland, on December 3rd, was the annual joint meeting with the American Electroplaters Society.

Mr. W. M. Philips, of General Motors Corporation, very ably discussed the "Quality of Plating." The subject of quality plating, as applied to automobile parts, covered inspection of actual car parts in service. Some of the tests used by General Motors to determine what constitutes real quality was a particularly interesting part of the discussion.

C. B. SANBORN, *Secretary-Treasurer*

New York Metropolitan Section

The New York Metropolitan Section met at the Holley Hotel, New York City, on November 10th.

Mr. Condon C. Henry, head of the R. C. A. office in Washington, D. C., and George Washington University Professor, delivered a very informative address entitled "A Better World."

In his talk, Mr. Henry dwelt on the vital significance of Industrial Research in our economy, and the possible effects of some current Government trends, particularly in regard to Patent Law. The speaker pointed out the great importance of our patent system in connection with the development of our industries. Attacks on this system, he says, endanger our 2,300 research laboratories distributed throughout the country, and the large sums of money expended for research ($177,000,000 in 1938).

An active discussion touching on all phases of Patent Law followed the talk.

J. S. MACKAY, *Secretary-Treasurer*

Midland Section

Mr. H. N. Bumpus, Customer Relations Supervisor of the Michigan Bell Telephone Company, talked to the members and guests of the Midland Section at their meeting in the Dow Auditorium on December 21st, on the subject, "Radar, Television and the Telephone."

Mr. Bumpus explained the part which Bell Telephone and its subsidiary, Western Electric Company, played in the development of radar during the last war, and demonstrated some of its properties with laboratory equipment. After defining the various terms and units used, he illustrated the properties of high frequency microwaves which behave very much like light. He showed the reflection of these waves, their polarity, and focusing, which is used to transmit microwaves by means of antennae on relay towers.

The speaker discussed the system between New York and Boston which employs seven such relay towers spaced 30 miles apart on high hilltops to obtain an obstacle-free path between towers. He also discussed the new Detroit-Toledo system which has two intermediate relay towers 180 feet high and showed pictures of this system. An additional system between Chicago and Milwaukee was briefly described. In all, there are five such microwave systems at present and each can be used to transmit either television programs or 480 telephone calls. These microwave systems are tied in with the coaxial cable systems which in middle January completed a television network from the Atlantic Coast to St. Louis, Missouri. This system should reach a sufficiently large prospective audience to make television a paying proposition for the first time commercially.

Mr. Bumpus also illustrated the flexibility of those high frequency radio waves by directing them around corners and through obstructions. Flexible hollow tubing was used similar to that em-

ployed to transmit these waves from the generating equipment to the masts of ships during the war, and in the buildings and around equipment of the Bell Telephone Company at present. Because of the fact that the present high terminal installation costs may be reduced, that there are no line costs contrary to the coaxial cable, and that microwaves are not affected seriously by weather, static, or man-made interference, Mr. Bumpus was of the opinion that the microwave system may be the system of the future. He also illustrated the coaxial cable which is covering the largest distances of the present television network and reported that terminal installation costs are cheap in this installation but that the line costs are high.

The third means of transmission mentioned is by ordinary wire in which 2400 separate calls may be handled in one lead sheathed cable.

The talk was well received by a large and enthusiastic audience.

Another feature of the program, that preceded the scientific address and was very entertaining, was a Standard Oil Company cartoon entitled, "Gasoline's Amazing Molecules."

F. W. KOERKER, *Secretary-Treasurer*

San Francisco Section

Dr. Raymond H. Ewell, Director of Chemical Engineering, at Stanford Research Institute, addressed the members of the San Francisco Section at their meeting at the St. Julien Restaurant on November 17th.

Dr. Ewell explained the role of electrochemical processes in the production of synthetic organic chemicals. It was pointed out that electrochemical processes are much more essential to the production of raw materials for these organic products than in the actual organic synthesis of the chemicals. The speaker likewise emphasized the economic and inter-competitive relationships of electrochemical and non-electrochemical products as raw materials for synthetic organic chemical industry.

R. F. BECHTOLD, *Secretary-Treasurer*

Ivan Bloch Announces New Firm

Ivan Bloch has announced the formation of a new firm to be known as Ivan Bloch and Associates, Industrial Consultants, located at 621 Park Building, 720 S.W. Alder Street, Portland, Oregon. Mr. Bloch was formerly a special consultant to Secretary of the Interior, J. A. Krug, and also a former Chief of the Division of Industrial and Resources Development at U. S. Bonneville Power Administration.

Mr. Bloch has taken a leading part in organizations promoting the industrial development of the Pacific Northwest. Further, he is a member of the Technical Advisory Committee of Oregon and Washington State Colleges, besides being prominent in many scientific societies.

The new firm will specialize in the industrial development of the Pacific Northwest and Alaska.

Personals

M. MERLUB-SOBEL has been appointed to the post of associate professor of chemical engineering and chemical metallurgy at the Hebrew Technical College in Haifa, Israel, the only school of applied science in that part of the Near East. At the same time, Dr. Merlub-Sobel is maintaining consultation and related practice.

ROBERT D. SCHWARTZ is now on a leave of absence from the Linde Air Products Company Research Laboratory, and is engaged as a graduate assistant at the University of Buffalo.

CLARE L. MILTON, JR., who was attached to the Army Prosthetics Research Laboratory at Washington, D. C., transferred recently to the Engineering Development Division, ANMPO, stationed at Fort Totten, New York, N. Y.

ERWIN SOHN is now associated with The National Sanitary Company, Salem, Ohio. Mr. Sohn was for many years connected with the Research Division of the American Radiator & Standard Sanitary Corporation, in Louisville, Kentucky.

LEON P. SUDRABIN has accepted a position with the Electro Rust Proofing Corporation in Belleville, New Jersey. Mr. Sudrabin was formerly with the Dayton Power & Light Company, Dayton, Ohio.

DR. JOHAN A. BJORKSTEN, President of the Bjorksten Research Laboratories, Chicago, Illinois, is at present at the Company's Research Laboratories in Madison, Wisconsin.

Frederick G. Cottrell

Dr. Frederick G. Cottrell, a well known scientist and inventor, died November 16th at his home in California. Dr. Cottrell had been a member of this Society since 1912. He is best known for his invention of the electrical precipitator so widely used for the precipitation of flue dusts, smokes, and which is also employed in air conditioning systems. In 1912 he organized the Research Corporation and assigned his patents to this organization which has been so fruitful in supporting fundamental research. Dr. Cottrell preferred the promotion of science to the accumulation of personal wealth.

Future Meetings of Other Organizations

Essex Electrical League, fifth electrical exposition, Mosque Theatre Building, Newark, New Jersey, March 8–11.

National Electrical Manufacturers Association, winter convention, Edgewater Beach Hotel, Chicago, Illinois, March 13–18.

Third International Lighting Exposition and Conference, Hotel Stevens, Chicago, Illinois, week of March 28.

19th Annual Safety Convention and Exposition, Hotel Statler, New York City, March 29–April 1.

American Gas Association, distribution, motor vehicle, and corrosion conference, Netherland Plaza Hotel, Cincinnati, Ohio, April 4–6.

Edison Electric Institute, 15th annual sales conference, Edgewater Beach Hotel, Chicago, Illinois, April 5–7.

National Association of Corrosion Engineers, annual corrosion conference, Netherland Plaza Hotel, Cincinnati, Ohio, April 11–14.

National Electrical Wholesalers Association, 41st annual convention, Netherland Plaza Hotel, Cincinnati, Ohio, May 1–6.

Instrument Society Spring Meeting in Toronto

The Fourth Annual Spring Meeting of the Instrument Society of America will be held at the Royal York Hotel, Toronto, Canada, May 12 and 13 according to an announcement by Ed Grace, Chairman of the National Meetings Committee and Chief Instrument Engineer of the Sun Oil Company.

The tentative program will include four technical sessions and a dinner on Thursday evening, May 12th. The technical program will be under the direction of Lyman Allen, Jr., Chairman of the Papers Subcommittee of the National Meetings Committee and Assistant Design Engineer, American Viscose Company. The meeting will be of interest to all engineers engaged in measurement, inspection, testing and automatic control.

New Members

At the meeting of the Board of Directors held on December 2, 1948, at the office of The Electrochemical Society, Inc., 235 West 102nd St., New York City, the following were elected to membership:

JOHN E. BARKLEY, Armour Research Foundation, 35 W. 33rd Street, Chicago 16, Illinois (Theoretical Electrochemistry, Batteries, Corrosion, and Electronics)

ELLSWORTH C. FRIDAY, National Carbon Company, Inc., 114 Sansome Street, San Francisco 4, California (Corrosion, Alkali and Chlorine, and Electrodeposition)

THERALD MOELLER, Noyes Chemical Laboratory, University of Illinois, Urbana, Illinois (Theoretical Electrochemistry and Electrodeposition)

HENRY E. ROBISON, Armour Research Foundation, mailing add: 4746 Kenwood Avenue, Chicago, Illinois (Theoretical Electrochemistry)

EMIL L. SHAKER, Chromium Corporation of America, mailing add: 22 Roseland Avenue, Waterbury, Connecticut (Theoretical Electrochemistry, Corrosion, and Electrodeposition)

CHESTER K. STERRETT, mailing add: Portland Chamber of Commerce, 824 S. W. Fifth Avenue, Portland 4, Oregon (Industrial Electrolytic)

KARL GUSTAF WRANGLEN, Division of Applied Electrochemistry, Royal Institute of Technology, Stockholm, Sweden (Theoretical Electrochemistry and Electrodeposition)

Reinstatement

ERNEST ASHWORTH, Battery Manufacturers Pty. Ltd., mailing add: 15 Trafalgar St. Mont Albert EIO, Victoria, Australia

Employment Situations

Please address replies to box shown, c/o The Electrochemical Society, Inc., 235 W. 102nd St., New York 25, N. Y.

Positions Available

RECENT GRADUATE, Chemical Engineer or metallurgist, for supervised research and development for electrolytic metals refining plant. Training in electrochemistry and general knowledge of nonferrous metallurgy essential. Submit resumé and salary requirements. *Reply to Box A-207.*

RECENT GRADUATE, trained in the modern advances in physical chemistry and familiar with electrochemical processes, ion exchange resins, absorption phenomena, etc. Large progressive chemical metallurgical corporation of the Middle West. *Reply to Box A-208.*

Positions Wanted

GRADUATING PH.D. in Chemical Engineering desires position in research. Two years industrial experience, three years naval officer experience. Age 28, married, one child. Middle Atlantic states location preferred. *Reply to Box 326.*

ELECTROCHEMIST, CH.E. with eighteen years extensive experience in many phases of electrodeposition, electroforming, metal finishing, etching, and related fields. Plant layout, installation development, research. Wide consulting background. Several outstanding developments in bright metal and alloy gold plating. *Reply to Box 327.*

POWDER METALLURGIST, graduate chemical engineer, 35, married, 13 years diversified experience in research, development, production in impregnated diamond tools, synthetic sapphire, cemented carbides, iron powder metallurgy, desires responsible position with progressive organization, preferably in diamond tool or in high temperature, metal-ceramic field. *Reply to Box 328.*

Recent Patents

Selected for electrochemists by Fred. W. Dodson, Chairman of the Patent Committee, from the Official Gazette.

October 19, 1948

Coleman, E. D., 2,451,663, Bridge Structure for pH Measurement Device.

Fry, D. R., 2,451,726, Dry Cell Depolarizing and Reconditioning Device.

Samuelson, W. H. E., 2,451,877, Method of Manufacturing Oscillator Plates.

Blau, M., 2,451,908, Method and Apparatus for Detecting Changes in Dimensions.

October 26, 1948

Hauck, V. D., 2,452,049, Combined Package and Filling Device for Batteries or Hollow Bodies.

Murphy, H. P., 2,452,066, Gas Diffusion Device for Storage Batteries.

Kennedy, T. R., 2,452,197, Induction Furnace for Variable Heat Patterns.

Lambros, G. C., 2,452,308, Process of Plating Palladium and Plating Bath Therefor.

Dyer, J. R., Jr., 2,452,361, Method for Electrolytic Deposition of Indium, and Bath Therefor.

Stivin, Jiri, 2,452,401, Method of Regeneration of Electron Discharge Devices.

Burns, L., 2,452,518, Nonactinic Fluorescent Lamp.

Leverenz, H. W., 2,452,522, Luminescent Screen and Method of Developing Light.

Leverenz, H. W., 2,452,523, Luminescent Screen.

Snoek, J. L., 2,452,529, Magnet Core.

Snoek, J. L., 2,452,530, Magnetic Core.

Snoek, J. L., 2,452,531, Process of Manufacturing a Magnetic Material and Magnetic Core.

Wainer, E., 2,452,532, High Dielectric Material.

November 2, 1948

Kotterman, C. A., 2,452,577, Dry Rectifier Element and Method of Manufacture.

Saslaw, O., 2,452,603, Metal Contact Rectifier.

Atlee, Z. J., 2,452,626, Electron Emitter.

November 9, 1948

Hartline, R. E., 2,453,318, Radioactivity Logging Device.

Davidson, N. R., 2,453,412, Electron Diffraction System and Method.

Piety, R. G., 2,453,456, Instrument for Measuring Water Flow in Wells.

Thumann, W. W., 2,453,474, Battery Terminal Clamp.

Wilson, A. B., 2,453,481, Anode for Electrolytic Coating.

Clark, F. M., and Raab, E. L., 2,453,493, Halogenated Hydrocarbon Composition.

Clark, F. M., 2,453,494, Fluorenone Dielectric Composition.

Letters To The Editor

Oral Presentation First?

Dear Sir:

I should like to voice a mild objection to publication of papers *before* their oral presentation. It appears quite useless to me to orate on a topic with which an audience is familiar through previous reading. Such time might better be given to discussion of the paper rather than an oral presentation. My preference is that of the Physical, Optical, and Chemical Societies where abstracts only are submitted, the papers presented orally, a discussion held, and then at some later date submitted for publication. Very often in this way an author can improve his paper tremendously by the criticisms and suggestions offered on his work during the discussion. In some cases it might even be necessary to carry on further experimentation before actual publication. By this method, too, an incomplete series might be reported—one which the author feels is important enough to be made public, but not complete enough to warrant publication at that time.

ARTHUR L. SMITH
Lancaster, Pennsylvania

Error Noted

Dear Sir:

Vol. 94, No. 3, page 35.V, United States Patent 2,400,297, "Apparatus for and method of electroforming of rectifier elements," is incorrectly numbered. The patent with this number is "Thermostatic vent valve for radiators."

This is sort of a left-handed way of indicating to you that the JOURNAL's contents are of interest to the reader and we continue to find the news section valuable and time-saving.

A. FLEISCHER
Hartford, Connecticut

Our apologies and thanks.—ED.

Book Reviews

COBALT by Roland S. Young. Published by Reinhold Publishing Corporation, New York, 1948. 181 pages, $5.00.

This monograph is the 108th in the American Chemical Society Series. It is written by the Chief Research Chemist for several African Mining Companies that are large producers of cobalt, and reflects the author's familiarity with the subject. The book is divided into 13 chapters in which the attempt is made to include everything pertinent to cobalt. This is a herculean task that the author has accomplished quite satisfactorily.

The general subjects covered in the book may best be described by listing the titles of the different chapters: 1. Historical and General, 2. Occurrence of Cobalt, 3. Metallurgy of Cobalt, 4. Chemical Properties of Cobalt, 5. Physical and Mechanical Properties of Cobalt, 6. Cobalt in Ferrous Alloys, 7. Cobalt in Nonferrous Alloys, 8. Cobalt in Powder Metallurgy, 9. Electroplating of Cobalt, 10. Cobalt Compounds in the Glass and Ceramic Industries, 11. Catalytic Behaviour of Cobalt, 12. Biological and Biochemical Relationships of Cobalt, and 13. Analysis of Cobalt.

It is to be regretted that the treatment of many sections of the monograph is necessarily brief, but this is compensated for, somewhat, by the rather general selection of references to the literature given at the end of each chapter. The references are for the most part, up to date, very few beyond the second chapter going back more than ten years.

In assembling and collating the widely scattered information on the chemistry and metallurgy of cobalt, the author has filled a need that has long been apparent. The American Chemical Society is to be congratulated for sponsoring the writing of this monograph and for selecting a writer so well qualified for the work.

The book is well printed and bound. This reviewer recommends the monograph to anyone who has an interest in any of the numerous aspects of the metal cobalt.

E. E. SCHUMACHER

VOLUMETRIC ANALYSIS, Volume II, by Kolthoff and Stenger. Published by Interscience Publishers, Inc., New York, 1947, 374 pages, $6.00.

The present volume is part two of an up-to-date revision of "Die Praxis der Massanalyse" which was originally published in 1928 by the senior author in collaboration with H. Menzel of Dresden, and later issued in an English translation by Dr. N. H. Furman. The theoretical principles of volumetric analysis have been dealt with in Volume I of this series. The present book is concerned with a critical discussion of the most important

methods of volumetric analysis involving acid-base, precipitation, and complex-formation reactions. Because of the need for including new material, the authors have reserved the material on oxidation-reduction reactions for a third volume which is scheduled for release later this year.

In the present volume, all of the essential material of the original version has been brought up to date, both as to content and presentation. In addition, a considerable amount of new material, especially on the subject of precipitation reactions, is included. One whole chapter is reserved for argentometric titrations, a field in which the senior author has long been active. On the other hand, no attempt has been made to cover exhaustively all applications of volumetric methods on specialized subjects in technical analysis. Instead the authors have tried to emphasize what they consider to be the important, useful, and reliable procedures most likely to be used.

The book is critical in nature, since the senior author has had personal experience with many of the methods described, and is thus of great value as a reference text to the advanced student of analytical chemistry as well as the research analyst.

There is no doubt but what the present revision is a worthwhile addition to all analysts' libraries and should enjoy, like the original, a unique place in the world's literature on analytical chemistry.

C. L. Luke

Metal Industry Handbook and Directory for 1948. Published by the Louis Carrier Co., Ltd., Dorset House, Stamford St. London SE1. 480 pages, given with *Metal Industry*, the annual subscription of which is £2 5s. 6d.

This handbook is an encyclopedia of British nonferrous metals and electroplating. It is divided into four sections. Section I, "General Properties and Mechanical Treatment of Metals and Alloys," includes properties of metals, metal statistics, tables of mechanical properties and physical constants, and descriptions of the nonferrous specifications issued by the various British Governmental Agencies.

Section II, "General Data and Tables," is a compendium of tables of gauges, weights, prices, and similar information.

Section III, "Electroplating," covers cleaning and plating methods and tables of interest to electroplaters.

Section IV, "Directory," is a listing of the British trade associations and a directory of manufacturers.

I. V. Williams

Recent Publications of the National Bureau of Standards

The following publications of the National Bureau of Standards have become available during the latter part of 1948. Copies may be obtained at listed prices from the Superintendent of Documents, Government Printing Office, Washington, 25, D.C.

Strain Tester for Rubber, William L. Holt, Ellis O. Knox and Frank L. Roth, 8 pp., 10 cents.

Description of a tester for measuring the strain of rubber vulcanizates when subjected to predetermined stress.

Dipole Moments and Molecular Association of Some Picrates of Primary, Secondary and Tertiary Amines in Benzene and Dioxane, Arthur A. Maryott, 6 pp., 10 cents.

A study showing how dipole moments of primary, secondary and tertiary amine salts of picric acid in dilute solutions of benzene and dioxane were determined from measurement of the dielectric constants of the solutions.

Acid-Base Equilibrium Constant and Dipole Moment of Tribenzylammonium Picrate in Benzene from Measurements of Dielectric Constant, Arthur A. Maryott, 3 pp., 10 cents.

A determination of the equilibrium constant and heat of reaction for the dissociation of tribenzylammonium picrate into picric acid and tribenzylamine in benzene at 30° and 40°C. The dipole moments of tribenzylammonium picrate and of picric acid were also computed.

Barium Aluminate Hydrates, Elmer T. Carlson and Lansing S. Wells, 7 pp., 10 cents.

Methods of preparation, optical properties and x-ray diffraction data for six barium aluminate hydrates.

Aliphatic Halide-Carbonyl Condensations by Means of Sodium, Edgar A. Cadwallader, Abraham Fookson, Thomas W. Mears, and Frank L. Howard, 8 pp., 10 cents.

An investigation of a method for synthesizing highly branched aliphatic hydrocarbons by interaction of alkyl halides and various carbonyl compounds in the presence of sodium.

Feature Section

The Profession of Electrochemistry

I. Electrochemical Engineering Invites the Young Graduate

*Colin G. Fink**

Electrochemical engineering is still the most inviting and now, more than ever, the most promising of all branches of engineering. The conversion of electrochemical laboratory discoveries and laboratory experiments into industrial processes is a most fascinating field of endeavor as well as a lucrative one.

The birth of the electrochemical industry as we know it today occurred shortly after the introduction of the dynamo by Edison and Siemens toward the close of the 19th century. The Aluminum Company of America recently celebrated its 60th birthday. Electrolytic copper refining is 72 years old; electrolytic alkali and chlorine 58; calcium carbide and carborundum 56; elemental phosphorus 55; Acheson graphite 52; and electric steel 50. It will be appreciated that the electrochemical industry comprising the above, as well as other products, is still an "infant" although a giant one. Its age, less than three quarters of a century, is as nothing when compared with 3000 to 4000 years, the age of the chemical and thermal processes which these electrochemical processes displaced.

Modern electrolytic copper of uniform purity and ductility is the very basis of our world wide electrical industry.

Importance of Aluminum

The metal which is most characteristic of the new metallurgy created by electrochemistry is aluminum. Powerful electric currents pass through fluid baths of salts of aluminum maintained at 1000°C. Tons of pure silver white aluminum metal collect at the cathodes. The metal is cast into ingots which are fabricated into a thousand different articles: structural parts for automobiles, railways, airplanes, ships, sky scrapers, cables, etc. etc. By a process similar to that for aluminum bright, light magnesium metal is today turned out by the ton. Then there is a long list of ferro alloys, such as ferro-silicon, ferro-chromium, ferro tungsten, that would be impossible without the electric furnace, a major tool of the electrochemist.

COLIN G. FINK

The list of commercial electrochemical products is now so long and varied that the young graduate may wonder as to what the future of electrochemistry holds for him. And our answer is: *The prospects are extremely good.* For example, in the field of the rarer metals, (zirconium, titanium, molybdenum, tungsten, beryllium, columbium, indium, thorium, and many more) the electrochemist is bound to discover new properties of these metals as well as new products. The young graduate with ambition and imagination is bound to succeed. He will discover products that will revolutionize modern industry and our modern way of living. Have you ever considered how badly handicapped we all would be if stainless steel, an electrochemical product, were no longer available?

* Head, Division of Electrochemistry, Columbia University, New York, N. Y.

Visits With Some European Corrosion Experts

Pierre Van Rysselberghe*

In the winter of 1933 I had the privilege of attending a series of lectures and experimental demonstrations on polarography given by the founder of this subject, Professor Jaroslav Heyrovsky of Charles University in Prague, Czechoslovakia. Dr. Heyrovsky was at that time touring the United States and, for most of his auditors, the subject of polarography and the beautiful machine designed by him were revelations, although the first publications in this field appeared as far back as 1922.

Polarography has now developed into a most important and useful subdivision of electrochemistry and its literature is accumulating at a rapid rate. About five years ago, my collaborators and I undertook a series of systematic researches in the field of polarography, largely because we felt that the information so obtained would be a valuable addition to our studies along the more traditional lines of electrochemistry. We quickly realized, however, that polarographic research had so many important possibilities, independently of its connections with other phases of electrochemistry, that several members of our group started devoting the greater part of their time to it.

Polarography and Corrosion

The remarkable features of the polarographic reduction of oxygen gave us the idea of basing upon it a study of the consumption of oxygen by metals dipping in various aqueous solutions. We submitted this idea to the Office of Naval Research in the spring of 1946. We also suggested that, besides oxygen, other polarographically reducible substances could be included (such as hydrogen ion, hydrogen peroxide, carbon dioxide, sulfur dioxide, etc.) in a general attack on the problem of corrosion by the polarographic method. The Office of Naval Research and the University of Oregon entered into a contract and since October 1, 1946, we have been pursuing a program of research under the general title of "Polarographic Study of Corrosion Phenomena." Except for possible renewal beyond that date, the original contract has been extended to October 31, 1949.

Having accepted an invitation to present a paper on the "Application of the Polarograph to Corrosion Studies" at the Gordon Research Conference scheduled for the end of July, 1948, at Colby Junior College, New London, New Hampshire, it occurred to me that I might increase the number of contacts with corrosion experts by extending them all the way to Europe.

PIERRE VAN RYSSELBERGHE

I was fortunate enough to obtain military air transportation through the very kind intervention of the Office of Naval Research. I thus traveled abroad for a period of about two months as a Naval Technician. My main purpose was to visit laboratories dealing with corrosion from fundamental electrochemical and thermodynamic viewpoints.

Being a newcomer to the field of corrosion research and being perplexed by the fantastic size and the unwieldy character of corrosion literature, I wanted to ascertain to what extent

* Department of Chemistry, University of Oregon, Eugene, Oregon.

fundamental lines of study are being followed. Our own polarographic approach is based upon fundamental physical chemistry and, through a visit to Professor H. J. McDonald's laboratory at the Illinois Institute of Technology and attendance at the Gordon Research Conference on Corrosion, I was able to obtain a general picture of the use of fundamental physical chemistry in corrosion research in this country. It is, however, interesting to note that through the many interesting remarks by Drs. C. Wagner, W. Beck, and others at the Gordon Conference, much of the important European work was also brought into the discussion.

Along with our polarographic work we have paid considerable attention to the thermodynamics of corrosion processes and my associate, Dr. P. Delahay, has calculated and drawn about fifty potential -pH diagrams for systems water-metal and water-non metal of the type first used by Dr. M. Pourbaix of the University of Brussels, Belgium.

Plans for Collaboration

I was able to have prolonged conversations with Dr. Pourbaix both in Brussels and in England at the Faraday Discussion, and we made detailed plans for the eventual publication of an atlas of these diagrams. Dr. Pourbaix's book of 1946 has been translated into English (by Dr. J. N. Agar at the request of Dr. U. R. Evans of Cambridge University) and into Italian (by Dr. R. Piontelli, then of the University but now of the Politecnico of Milan), both translations being due to appear within the coming months.

In addition to these publication plans, Dr. Pourbaix and I outlined a project of international collaboration in the field of electrochemistry by which electrochemical studies and their applications to corrosion would be carried out according to a concerted program. A number of persons contacted by Dr. Pourbaix (such as Drs. W. G. Burgers at Delft, Holland, A. Juliard at Brussels, R. Pointelli, and others) have expressed enthusiastic approval. Support may eventually be sought for UNESCO or one of the Commissions of the International Union of Pure and Applied Chemistry. The reaction of the members of The Electrochemical Society would be heard with interest. In Brussels also discussions were held with Professor I. Prigogine on electrochemical thermodynamics.

From Belgium I proceeded to Germany where my main goal was to call on Professor G. Masing, the well-known corrosion expert at the University of Göttingen. I found him actively engaged in polarization studies on aluminum and other metals, but handicapped by serious material limitations in the way of equipment and current scientific literature. Fully aware of the constantly increasing interest in metals such as titanium and zirconium, Professor Masing intends to carry out detailed determinations of polarization curves for these metals.

Conditions in Germany

In the course of conversations with him and other Göttingen professors, the sad plight of German science, the nearly complete destruction of all but four of the academic chemical institutes (the four "survivors" being Erlangen, Göttingen, Heidelberg, and Tübingen) was brought home to me in a most depressing manner. A meeting scheduled for the end of August at the Technical University of Berlin-Charlottenburg, on "Science, Technology, and Humanity" and to which I was to represent the American Chemical Society, was canceled on account of the complicated situation in the former German capital. I thus kept clear of Berlin and, after visits in Frankfurt, Heidelberg and Stüttgart, I entered Switzerland with a feeling of definite relief.

My first visit was to the control and research laboratories of the Aluminium Industrie Akt. Gesell. at Neuhausen am Rheinfall near Schaffhausen.

Aluminum Plants in Switzerland

The aluminum extraction and fabrication plants are at Chippis in the Canton of Valais, the administrative offices in Lausanne. The admirably equipped corrosion and testing laboratories are under the direction of Professor A. von Zeerleder of the Swiss Federal Institute of Technology in Zürich. I had a most interesting and useful visit under the guidance of Drs. E. Herrmann and E. Zurbrügg. Most of the methods used in these laboratories are standard ones, but they are carried out with the greatest possible precision afforded by high-quality modern Swiss equipment. Electrochemical studies are not specially developed, the polarograph, for instance, being used only in a few routine analytical procedures. The personnel

seemed to regret the lack of opportunities for fundamental research. Similar remarks, both as regards the excellence of the equipment and as regards the absence of fundamental research, apply to the very interesting laboratories of Sulzer Brothers, the well-known firm associated with the development of the Diesel engine, at Winterthur, where I had a very instructive visit with Director Dinner, Chief Engineer Felix, and Chief Chemist Heuss.

At Zürich, besides a general tour of the extensive chemical laboratories of the Swiss Federal Institute of Technology, I visited in detail the corrosion section of the "Eidg. Materialprüfungs und Versuchsanstalt für Industrie, Bauwesen und Gewerbe," directed by Professor P. Schläpfer, where I had a useful discussion with the assistant in charge of corrosion, Dr. A. Bukowiecki. I was favorably impressed by the great thoroughness and novelty of the investigations being carried out in this laboratory. One of their important features is the constant concern with water and oxygen dissolved in corroding organic media. An imposing amount of useful data on solubilities and rates of dissolution of water and oxygen in organic liquids will be forthcoming from this laboratory.

Dr. Feitknecht's Laboratory

From Zürich, I proceeded to Bern, the Swiss federal capital, where I visited Professor W. Feitknecht's laboratory in the chemistry division of the University. Dr. Feitknecht's work is rather well known in this country. Of all laboratories visited during my trip abroad, this one impressed me as being the most complete and systematic in its methods of attack on the general problem of corrosion. No aspect of corrosion seems to be left out: examination of the exact composition and structure of the various corrosion products from the point of view of the chemistry of inorganic complexes in which Dr. Feitknecht is an expert, physical chemical investigations on local galvanic elements, x-ray and electron microscope examinations of the corrosion products (the electron microscope, of Swiss construction, being in use nearly twenty-four hours a day), simultaneous studies on aqueous and dry corrosion, etc. The assistants and research students all seemed extremely keen and had numerous useful ideas to discuss. I had a fruitful discussion with Dr. E. Wyler on the role of hydrogen peroxide and carbon dioxide in corrosion, some of the observations in the Bern laboratory being similar to our own.

A visit was also paid to the physiology laboratory of the University, where the oscillographic method of registering polarograms due to Dr. S. Weidmann was examined and discussed in a most interesting fashion with Dr. R. Stämpfli. A somewhat similar method is now being used in our corrosion research at the University of Oregon.

Milan and Dr. Piontelli

From Bern I took a side trip to Milan, Italy, for the purpose of calling on Professor R. Piontelli, the well-known electrochemist and recent contributor to this JOURNAL. At that time Dr. Piontelli was still connected with the University of Milan but, as he then expected, he has now joined the Politecnico as director of the advanced courses in electrochemistry, physical chemistry, and siderurgy, the post held until a few years ago by the late Scarpa.

My visit with Dr. Piontelli was perhaps the most fruitful one of the whole trip. I found in this distinguished scientist an endless source of useful information on the electrochemical theory of corrosion, on electrochemical thermodynmics, etc. He has, moreover, the most complete private library on these and other physical chemical subjects that I have seen. There would be no better place to write, for instance, a history of thermodynamics, a circumstance I hope to take advantage of in a not too distant future. Dr. Piontelli is in very close touch with activities in electrochemistry and corrosion elsewhere in Europe and he would be an essential pivot in the international program mentioned above.

Visits in France

In France, my visits were all in, or close to, Paris. I had been told by several experts, particularly in Switzerland, that the best industrial corrosion laboratory, from the point of view of fundamental research, is that of the "Société d'Electrochimie, d'Electrométallurgie et des Aciéries Electriques d'Ugine" in the French Alps and that, in particular, the work of Guitton and Castro on stainless steels was of very great interest.

I was, unfortunately, unable to visit this laboratory but called at the headquarters of the firm in Paris. This work

on stainless steels, as well as a great deal of other important French work, is available in the journal *Métaux et Corrosion* which deserves to be better known in this country. Another interesting corrosion laboratory is that of the "Aluminium Français" at Chambéry.

Corrosion Work at the Sorbonne

The most active group in corrosion research in France at the present time is no doubt that of Professor G. Chaudron of the Sorbonne. All the experimental work is carried out at the "Laboratoire Central des Traitements Chimiques," an extremely well equipped organization located at Vitry-sur-Seine, very near Paris. Drs P. Lacombe and L. Moreau showed me in detail their respective divisions. Much of the work is based upon the use of large single crystals of metals. One of the main preoccupations in the corrosion work is the variation of properties with the degree of purity. The work done on high-purity aluminum and on electro-polished aluminum (for instance the variations of dissolution potentials and of polarization curves resulting from increased purity and polishing) is of considerable interest. (See, for instance, Prof. Chaudron's recent article on high purity aluminum in *Helvetica Chimica Acta*, 1948.)

Industrial Chemistry Congress

Among other contacts in France, I wish to mention an interesting visit with Professor G. Valensi of the University of Poitiers, an authority on dry corrosion and an expert in applied thermodynamics, a visit to the corrosion laboratories of the "Ministère de l'Air," and also an extensive visit to UNESCO headquarters. From Paris I returned to Brussels, where, in the middle of September, I attended the Congress of Industrial Chemistry. More than twenty countries were represented and I presented a condensation of my communication at the Gordon Conference. A very interesting discussion of the polarographic method was held the next day.

After leaving Brussels I returned to London where I had stopped briefly in early August. My first visit was to the "British Non-Ferrous Metals Research Association" where the corrosion section is under the direction of P. T. Gilbert with R. May as adviser and senior investigator. Director G. L. Bailey and Research Manager A. G. Quarrell received me most kindly and I had the opportunity of extended discussions with a number of other staff members. Summaries of the many important corrosion studies carried out in this laboratory are available in the Annual Report published in June, 1948. Our work on the role of hydrogen peroxide and carbon dioxide in corrosion was profitably discussed during my visit. Polarographic work was at one time attempted in this laboratory in connection with the role in corrosion of certain organic constituents of sea water.

The Teddington Laboratory

Another fruitful visit was that to the corrosion division of the "Chemical Research Laboratory, Department of Scientific and Industrial Research" at Teddington. This laboratory is a neighbor and close associate of the National Physical Laboratory. Corrosion research is under the direction of Dr. W. H. J. Vernon with whom I had a very pleasant visit. An interesting connection with three corrosion experts, met during my trip, is the following: W. H. J. Vernon, W. Feitknecht, and R. May were classmates at the Imperial College, London, and were thus similarly trained. Dr. Vernon has given an excellent summary of the activities of his laboratory in a communication at the "Journées sur la Corrosion des Métaux" in Paris. Dr. F. Wormwell showed me in detail the various investigations pursued at present in this laboratory. He was interested by the possibilities of the polarographic method in the exploration of the first stages of corrosion to which the method of the late Dr. G. D. Bengough of this same laboratory cannot be applied. Both here and at the British Non-Ferrous laboratory investigators are quite preoccupied with microbiological corrosion, the Teddington laboratory having a well developed section entirely devoted to it. Its role in underground corrosion seems to be fundamental.

Attends Faraday Discussions

Between visits to corrosion laboratories I attended the Faraday Society Discussion held this year in the beautiful estate now owned by the British Iron and Steel Institute at Ashorne Hill, near Leamington Spa, Warwickshire. The evening preceding the meeting, the

officers of the Iron and Steel Institute were hosts to the foreign participants of the Faraday meeting at a delightful banquet in the Hyde Park Hotel in London. The meticulous organization of the Faraday Discussion, its high level at all times, the program of excursions, and all the other features of this type of meeting should serve as examples to other scientific organizations. The papers dealt with attempts at using exact physical chemistry in the field of high temperature reactions. The preprints had been sent to the participants in advance and the sessions were devoted almost entirely to discussion. One of the main contributions to the program was that of Professor Chipman of Massachusetts Institute of Technology.

As usual at meetings like this one of the most profitable activities was casual conversation outside of the regular sessions. I had the good fortune of meeting at Ashorne Hill a number of corrosion investigators. I wish to mention in particular Dr. P. Herasymenko, one of the early collaborators of J. Heyrovsky in the field of polarography, who told me that, twenty years ago, he had suggested to some English metallurgists the use of the polarograph for the detection of hydrogen peroxide in corrosion reactions. His suggestion was not followed, but the idea is precisely one of the main features of our polarographic corrosion research.

Dr. Evans' Methods

After the Faraday Discussion I went to Cambridge and called on Dr. U. R. Evans whose classical corrosion research is well known in this country. I was struck by the simplicity of his methods and ideas and he told me that he liked our polarographic method precisely because of its simplicity. Dr. Evans' laboratory reflects this striving for simplicity in its organization and equipment. That such fundamental work as his can be carried out in this manner should be a lesson to the many workers who feel that they cannot accomplish anything unless they have the use of the most elaborate and expensive type of equipment. I also had a profitable visit with Dr. J. N. Agar whose work on reduction of oxygen on still mercury electrodes has interesting connections with ours. I had seen Dr. T. P. Hoar, collaborator of both Drs. Evans and Agar, at Ashorne Hill.

Value of European Research

As a whole, a trip like the one related in the foregoing paragraphs shows that there is a great deal of important and useful research in the field of corrosion being carried out in Europe at the present time in spite of the many material difficulties resulting from the war. Much of this work, particularly that published in languages other than English, is insufficiently known in this country. Several continental scientists remarked to me that their work was apparently unknown in this country because it was not published in English. I cannot do better than to endorse Dr. U. R. Evans' comments on this matter in the November, 1948, number of *Corrosion*.

Soon after my Cambridge visit I started my flight back to the United States, via Scotland, Iceland, and Labrador as on the way over, and, after a brief stop in Washington and a visit with my sponsors of the Office of Naval Research, I found myself back to actual corrosion research and the many varied duties of a professor.

Make Reservations Early for

The 95th Meeting of The Electrochemical Society

Held at the Benjamin Franklin Hotel in Philadelphia May 4, 5, 6, and 7, 1949

Sessions on
Luminescence, Rare Metals, and Theoretical Electrochemistry

Survival Through Chemistry

Men of good will who propose "Freedom from Want" and an American standard of living for all of the people of the world do not comprehend the impossibility of accomplishing this goal without rigid control of population growth. Even to maintain in this country alone the living standard to which it has become accustomed will require greater intelligence in the management of our natural resources and a better public understanding of the dangerous consequences of the misuse of lands, forests, and minerals. Biologists have pointed out recently in thought-provoking books that, while the population of the world has doubled in the past hundred years, many millions of acres of land have become exhausted beyond hope of recovery. There remains about one acre of arable land per capita to sustain the world's present population and the biotic potential of this land is declining steadily. The half acre of poor soil for each person in Puerto Rico affords but miserable support to a population which has doubled since this territory became an American possession. The nationalistic spirit that leads nations to encourage population growth is fundamentally unsound; in the past it has led to wars and in the future it can lead only to starvation.

There is no question that we have dissipated our resources as though we believed nature's store-house inexhaustible or man's ingenuity capable of supplying the deficiency. Scientists, upon whom must fall the task of supplementing nature, have been the first to urge more effective conservation measures, and they themselves have made many contributions in this direction. Biologists have shown how to obtain the optimum productivity of soils, and chemists have learned how to extract metals from low grade ores and how to utilize more fully and economically plant and animal resources. The first step toward the release of larger acreages of land for food crops has been made possible by the chemical synthesis of clothing materials. Ultimately, however, it may be necessary to base the synthesis of both food and clothing upon the more elemental substances, carbon dioxide, water, and air. A program of basic research should lead to a suitable process for the synthesis of carbohydrates, but for protein foods it may be necessary to depend upon the action of yeasts fed upon a diet of fixed nitrogen compounds. In any case, the discoveries of the coming chemical age will have an important bearing upon man's survival.

R. M. B.

Current Affairs

Excellent Program for Philadelphia

One of the largest and most attractive technical programs in the history of the Society is planned for the Philadelphia meeting to be held from May 4th through May 7th. More than seventy papers will be presented with adequate time for discussion. Special features of the program will be three symposia on the subjects Luminescence, Rare Metals, and Theoretical Electrochemistry. In addition, there will be miscellaneous papers on corrosion, electrodeposition, electrowinning, electro-organic chemistry, and batteries. While the regular symposium of the Corrosion Division has been moved to the fall meeting, the promise of four papers on corrosion, two of which are by such well known experts as R. B. Mears, W. A. Wesley and H. R. Copson, should attract those interested in the field.

Symposium on Luminescence

Since there are likely to be more than twenty papers on the general subject of luminescence, including contributions from several foreign scientists, this symposium will run a full day.

Titles of some of the papers are:

"High Valency Manganese as Activator of Luminescence"

"On the Decay of Phosphorescence and the Mechanism of Luminescence of Zinc Sulfide Phosphors"

"Chemical Proof of the Presence of Chlorine in Blue Fluorescent Zinc Sulfides"

"The Preparation of Luminescent Screen"

"The Use of Fluorescent Dyes as Tracers in Biology and Medicine"

"Double and Triple Activated Magnesium Pryophosphate Phosphors"

"Calcium Halo Phosphate Phosphor"

Symposium on Rare Metals

A large number of papers have been received for the Symposium on Rare Metals, assuring that this program sponsored by the Electronics Division will be a successful one. Papers received indicate that the program will cover in-

BENJAMIN FRANKLIN PARKWAY SHOWING PHILADELPHIA SKYLINE

teresting discussions of such metals as cerium, tellurium, platinum, titanium, silicon, germanium, lithium, and tantalum.

Symposium on Theoretical Electrochemistry.

This welcome addition to the Philadelphia program has elicited much favorable response from members and those contributing papers. A generous amount of time will be allotted to the presentation of each of the papers in this group and, from all indications, the discussions of these papers will be stimulating. Titles of some of the papers which will be included on the program are:

"Some Observations on the Potential of the Manganese Dioxide Electrode"
"The Role of Natural Convection in Electrolytic Processes"
"The Electrodeposition Behavior of a Simple Ion"
"A Study of the Separation of a Trace of Silver from a Macro Amount of Palladium by Electrolysis"
"The Electron Affinity of the Carbon Atom"
"Applications of Electrophoresis to Allergy"
"Thermionic Emission from Carbon"

Round Table Discussions

Among the round table discussions that are creating keen interest as a part of the Philadelphia program are the Industrial Electrolytic Division's session on "Materials of Construction for Chlor-Alkali Plants," and the Electrothermic Division's discussion on "Special Melting Techniques for Metals."

The discussion on "Materials of Construction for Chlor-alkali Plants" will be considered from two angles, namely, (1) from the standpoint of requirements of various processes, and (2) from the standpoint of the properties of various processes.

Chlor-Alkali producers and equipment suppliers will have the opportunity of drawing upon the experience of many experts in the field for the discussion of their problems.

Since time is short, and the scope of the round table unlimited, it would be helpful in the preparation of a rough outline to have suggestions or contributions of special interest communicated, in advance of the meeting, to the Secretary of the Division: M. S. Kircher, Hooker Electrochemical Company, Niagara Falls, New York.

The round table on "Special Melting Techniques for Rare Metals" will be held in conjunction with the symposium on "Rare Metals," sponsored by the Electronics Division. Mr. N. E. Promisel, Navy Department, Bureau of Aeronautics, will act as moderator. Announcements of the panel members for this round table discussion will be made before the meeting. The committee anticipates considerable participation.

BENJAMIN FRANKLIN HOTEL
CONVENTION HEADQUARTERS

Attractive Program for the Ladies

A ladies' committee has been organized by Dr. Harry Alsentzer, Chairman of the Entertainment Committee, to arrange the various activities for each day of the Convention. The plans are being enlarged at present and a very attractive program is expected to result.

On Thursday morning, May 5th, there will be a get-acquainted gathering, followed by a special luncheon at one of the city's interesting restaurants at which time the ladies will be the guests of the Philadelphia section. For the afternoon

Photos courtesy of Philadelphia Convention & Visitors Bureau.

a trip has been arranged to a number of points of interest in Philadelphia and vicinity. On Thursday evening the ladies will attend the President's Reception and Dinner.

Friday morning will probably be reserved for individual sightseeing trips and shopping. Philadelphia's stores and specialty shops as well as its many famous landmarks provide ample opportunity. On Friday, also, there will be a luncheon for the ladies at one of the historic colonial hostelries near Philadelphia, and in the afternoon a visit to the famous Du Pont Gardens at "Longwood."

The Entertainment Committee is making every effort to see that this program will be most enjoyable, and further details will appear in the Journal as they are completed.

Plant Trips

On Friday afternoon, an opportunity will be given to take one of two plant visits. The first trip will be to the plant of Leeds and Northrup Company, manufacturers of scientific instruments. The second trip will be to the new laboratories of the Pennsylvania Salt Manufacturing Company, which are housed in the former palatial residence of E. T. Stotesbury at Whitemarsh. From there, those on the trip will go the Eastern Regional Research Laboratory of the U. S. Department of Agriculture.

General Entertainment

The President's Reception and Dinner will take place on Thursday evening, May 5th, and will be followed by dancing.

On Friday evening, May 6th, following the plant trip, a buffet supper will be served which will be followed by an evening of entertainment arranged by the Philadelphia Section. This, we are assured, will be fully up to the standards which have been established in the past.

Complete Program

The program booklet with complete details of the technical and social features planned for the convention and hotel reservation cards will be mailed to members about April 1st. In the meantime it will be well to underscore May 4, 5, 6, and 7 on the calendar for these will be red-letter days for all electrochemists.

CONVENTION COMMITTEE MEETS TO PROMOTE PHILADELPHIA PLANS

Seated (left to right): H. Jermain Creighton, Hiram S. Lukens, Russell P. Heuer, Ernest G. Enck, Chairman. Standing (left to right): Arthur Osol, Edgar L. Eckfeldt, Milton B. Barba, John F. Gall, J. F. Hazel, A. A. Ware, Harry A. Alsentzer. Other Committee members not shown in picture: R. H. Cherry, J. L. Crenshaw.

Section News

Detroit Section

The Detroit Section continued its 1949 program at the Sheraton Hotel in Detroit on January 21st. The speaker at this time was Dr. Robert Gessell of the Physiology Laboratory of the University of Michigan. The topic for discussion was "Some Electrochemical Aspects of Neuro-Physiology."

Dr. Gessell's talk dealt mainly with the physiology of the neurone and an attempt to show how the nerve cell body, its dendrites and neuraxon and its synapses function. He began with a description of Galvanic experiments indicating the existence of animal electricity and followed with confirmatory experiments. He then discussed the nature of the nerve impulse and the mechanism of its transmission, relating the structure of the nerve cell body, and its dendrites to the function of the neurone. Dr. Gessell advanced the idea that the long employed theory of synaptic transmission of nerve impulses through reflex arcs is incompatible with known facts and offered in its place a theory of neurocellular generation of nerve impulses. According to this theory the nerve cells and their dendrites serve as electrochemical generators of nerve impulses. In conclusion, he considered the source and physiological gradation of the intensity of this current of generation of nerve impulses.

M. L. Baty, *Secretary-Treasurer*

New York Metropolitan Section

The Winter Dinner Meeting of the New York Metropolitan Section was held on February 2nd at the Holley Hotel, New York City.

A social period preceded the dinner, and the technical meeting followed with Mr. J. H. Winkler, Technical Advisor, Battelle Memorial Institute, delivering an address on "Recent Advancement of Printing Products."

Mr. Winkler has had seventeen years' experience in commercial plate production for letter press printing and twelve years' experience in printing production research, originally at the National Bureau of Standards and recently at Battelle Memorial Institute. He is the author of many articles pertaining to the graphic arts.

In his talk, Mr. Winkler gave a very interesting review of the history of printing and its present status in our society. It is now a 4.5 billion dollar industry, and if paper pulp is included, it is approximately 9 billion dollars. This latter bracket puts printing near the top of U. S. industries. Because of economic pressure, the industry has been forced to do research on new methods. The speaker reviewed present production processes, new developments, and possibilities for the future. Important among recent research achievements is the new Battelle development of xerography and xeroprinting which Mr. Winkler explained. Exhibits of these and other developments were shown with the explanations.

J. S. Mackay, *Secretary-Treasurer*

Philadelphia Section

The second meeting of the 1948–49 year of the Philadelphia Section was held on January 5th in the Harrison Laboratory, University of Pennsylvania. A dinner at the Lenape Club in honor of the speaker, Professor Hiram S. Lukens, preceded the meeting.

Dr. Lukens, Blanchard Professor of Chemistry and Director of the Department of Chemistry and Chemical Engineering at the University of Pennsylvania, has been active in the affairs of The Electrochemical Society and was its thirty-first president. He has pioneered many developments in both theoretical and applied electrochemistry.

Professor Lukens addressed the Section on "A New Method of Eliminating Porosity in Electrodeposited Metals." The talk dealt with the effect of various factors on the corrosion resistance of silver plate with steel as the basis metal. The speaker's interest in the problem was traced to his association with the War Metallurgy Committee at the time the latter was assigned the job of improving the tableware used by the armed services.

The effects of plate thickness and of the presence and quality of the undercoat on the porosity and corrosion resistance were discussed. It was shown that polarization of the silver plate as anode in a chloride bath resulted in the formation of silver chloride and silver oxide. Heating decomposed the silver oxide and melted the silver chloride. The latter, because of its good wetting properties, flowed over the metal and filled the pores of the silver plate.

About forty-four members were pres-

ent at the dinner and about seventy attended the technical meeting.

J. F. HAZEL, *Secretary*

San Francisco Section

A dinner meeting was held by the San Francisco Section at the St. Julien Restaurant, San Francisco, on January 19th.

Dr. A. C. Byrns, Director of Research at The Permanente Metals Corporation, addressed the meeting on the subject "The European Aluminum Industry." The basis of Dr. Byrns's discussion was a recent trip to Europe to observe the operation and development work of aluminum reduction plants in England and France. Part of his talk concerned his observations of political and economic conditions in these countries and also the differences in development technique and the method of application of new ideas between English, French, and American aluminum producers. The remainder of the discussion concerned the basic principles and design of aluminum cells and the more recent developments in their design, both American and European.

The talk evoked keen interest and was followed by a lively question and answer period.

The frequent and pleasurable meetings of the San Francisco Section augur well for its continued growth and success.

R. F. BECHTOLD, *Secretary-Treasurer*

Future Meetings of Other Organizations

Third International Lighting Exposition and Conference, Hotel Stevens, Chicago, Illinois, March 29–April 1.

19th Annual Safety Convention and Exposition, Hotel Statler, New York City, March 29–April 1.

American Gas Association, distribution, motor vehicle, and corrosion conference, Netherland Plaza Hotel, Cincinnati, Ohio, April 4–6.

Edison Electric Institute, 15th annual sales conference, Edgewater Beach Hotel, Chicago, Illinois, April 5–7.

National Association of Corrosion Engineers, annual corrosion conference, Netherland Plaza Hotel, Cincinnati, Ohio, April 11–14.

National Electrical Wholesalers Association, 41st annual convention, Netherland Plaza Hotel, Cincinnati, Ohio, May 1–6.

American Gas Association production and chemical conference, Hotel New Yorker, New York City, May 23–25.

American Society of Refrigerating Engineers, 36th spring meeting—cruise, St. Lawrence and Saguenay Rivers, starting from Montreal, June 5–9.

American Institute of Electrical Engineers, summer general meeting, New Ocean House, Swampscott, Massachusetts, June 20–24.

American Society of Heating and Ventilating Engineers, semiannual meeting, Minneapolis, Minnesota, June 21–23.

Uhlig Appointed Editor

By action of the Board of Directors, Professor Herbert H. Uhlig of Massachusetts Institute of Technology will become editor of the JOURNAL and TRANSACTIONS of The Electrochemical Society on April 1st. At the same time, Miss Eleanor Reid will become managing editor; Professor H. B. Linford of Columbia University and Mr. U. B. Thomas

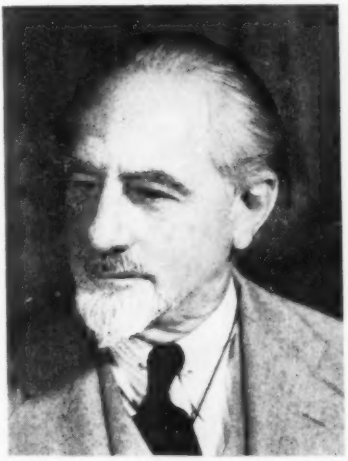
H. H. UHLIG

of Bell Telephone Laboratories will become associate editors. Dr. R. M. Burns, the present editor, will continue his association with the Society's publications in the capacity of editorial consultant.

Professor Uhlig, who is director of the Corrosion Laboratory at the Institute, has been a member of the Society since 1938. He was editor-in-chief of the *Corrosion Handbook* which is proving so popular.

Board Chairman of Dorr Company

Dr. John Van Nostrand Dorr was elected Chairman of the Board of The Dorr Company, internationally known engineering firm, and Elmer R. Ramsey succeeded to the presidency. The announcement was made on January 24th at a dinner given in their honor at the University Club, New York, by some fifty senior members of the staff. Dr. Dorr is the founder of the Dorr Company and has been its president for nearly forty years.



JOHN VAN NOSTRAND DORR

Dr. Dorr, an early associate of Thomas A. Edison, is widely known for his inventions of equipment and processes used in continuous unit operations in ore dressing, chemical operations, and sewage and water purification. They are in use throughout the world and have made possible the large production of metals from low-grade ores. He has long been a member of The Electrochemical Society and is a holder of the Perkin Medal and other medal awards.

Dr. Dushman Retires from G-E Research Laboratory

Dr. Saul Dushman, assistant director of the General Electric Research Laboratory since 1928, and an international authority on high-vacuum research, retired December 31, 1948, after 37 years as a G-E scientist. Dr. Dushman will return to the laboratory in the spring as a consultant.

Dr. Dushman's early work was in the field of electron emission from hot filaments, which provided basic information in the development of electron tubes. He then began to investigate the production of high vacuum. This continued to the present and made him an international authority in this field.

Another outstanding quality of Dr. Dushman's is his deep interest in the human side of laboratory activities. Because of his efforts for the welfare of the members of the staff, he became known as unofficial "dean of men" and was described by his colleagues as "the laboratory's greatest morale builder."

Personals

V. S. DE BEAUSSANT recently went to Shanghai, China, in the employ of the J. G. White Engineering Corporation. Mr. De Beaussant spent some time in the United States during the past year, after returning from India, where he went after the war.

FRANK M. CLARK of the General Electric Company has transferred from the company's plant at Pittsfield, Massachusetts, to the Research Department of the company at Schenectady, New York.

BERNARD A. GRUBER is now on the staff of Battelle Memorial Institute, Columbus, Ohio. Mr. Gruber was formerly in the Plating Laboratory of the Harshaw Chemical Company at Cleveland, Ohio.

FRED P. PETERS, formerly Editor-in-Chief of *Materials & Methods*, Reinhold Publishing Corporation, has been elected a Vice-President of the Corporation and Publishing Director of the Book Division.

A. L. PIETROWICZ, together with his associates R. E. Driscoll and J. W. Fogarty, announces the opening of the plant and offices of Cover-Rite, Inc., at 1714 West Division Street, Chicago, Illinois. The new firm will specialize in all kinds of plating and metal finishing. Mr. Pietrowicz was formerly with the Chicago Plating Company.

T. L. RAMA CHAR, a member of this Society connected with the Indian

Institute of Science at Bangalore, has been elected an associate of the Institute of Physics of London. It is of great interest to note that Dr. Rama Char is undertaking the organization of a Local Section of the Electrochemical Society with headquarters at Bangalore.

FRANCIS M. TURNER, who has been Publishing Director of the Book Division of Reinhold Publishing Corporation since 1915, is relinquishing this post in order to give special attention, as Vice-President of the company, to author contacts.

CHARLES A. MARLIES

It is with sincere regret that we report the untimely death at the age of 43 of Dr. Charles A. Marlies, Associate Professor of Chemical Engineering at the College of the City of New York.

Dr. Marlies was graduated from The City College and Columbia University receiving his Ph.D. degree from the latter in 1935. He taught at City College for many years, first in the Department of Chemistry, and more recently in Chemical Engineering.

Dr. Marlies was a visiting professor at New York University for several years, and president of the City College Engineering Alumni at his death. He was a former chairman of the New York Bureau of Cooperative Medicine and a former president of the Group Health Cooperative.

In addition to The Electrochemical Society, of which he was chairman for the New York Section in 1938, Dr. Marlies was a member of many scientific groups and wrote extensively on topics in his field. He was co-author of the recently published "Principles of High-Polymer Theory and Practice."

Volumes Available

Dr. B. B. Baschkin has a set of the "Zeitschrift f. Elektrochemie" 1900–1938, and the General Register 1905–1924, which he is offering for sale. Dr. Baschkin's address is: Syracuse University, Skytop M.R. 16, Syracuse, New York.

New Members

At the meeting of the Executive Committee held on January 5, 1949, at the office of The Electrochemical Society, Inc., 235 West 102nd St., New York City, the following were elected to membership:

WILLIAM KARL ACKERMANN, mailing add.: Ray-O-Vac Company, 212 E. Washington Avenue, Madison, Wisconsin (Batteries and Corrosion)

V. ARAVAMUTHAN, Indian Institute of Science, mailing add.: 1850/2 Ambalpuram, Sandapettai, Pudukotah, (Via) Trichinopoly, South India (Electrothermic)

JOSEPH H. AREHART, Electroforming Division, U. S. Rubber Company, mailing add.: 120 East Avenue, Norwalk, Connecticut (Electrodeposition)

CARLOS CAVA DE LLANO, Auxiliar Textil Alba, S. A., mailing add.: Herzegovino, 28 bis 1°, Barcelona, Spain (Theoretical Electrochemistry, Organic Electrochemistry, and Electrodeposition)

DANIEL CUBICCIOTTI, JR., mailing add.: Department of Chemistry, Illinois Institute of Technology, 3300 S. Federal Street, Chicago 16, Illinois (Theoretical Electrochemistry and Corrosion)

HERBERT WILLIS DENT, JR., American Cast Iron Pipe Company, mailing add.: 5901 First Avenue North, Birmingham, Alabama (Corrosion)

SAMUEL HAROLD DREISBACH, University of Michigan, mailing add.: 1014 Cornwell Place, Ann Arbor, Michigan (Theoretical Electrochemistry and Electrodeposition)

WILLIAM NEVIUS DUNLAP, JR., Michigan Chrome & Chemical Company, mailing add.: 1735 Lloyd Avenue, Royal Oak, Michigan (Theoretical Electrochemistry, Corrosion, and Electrodeposition)

ROBERT CHARLES DUNN, The Permanente Metals Corporation, mailing add.: 1047 Orange Avenue, San Carlos, California (Theoretical Electrochemistry, Electrodeposition, and Electrothermics)

FRANK M. GOYAN, University of California, mailing add.: 625 Ashbury Street, San Francisco 17, California (Theoretical Electrochemistry)

MILTON B. HAMMOND, Standard Steel Spring Co., mailing add.: 317 Meadow Lane, Edgeworth, Sewickley, Pennsylvania (Electrodeposition and Theoretical Electrochemistry)

GEORGE S. HARTMAN, Electric Storage Battery Company, mailing add.: 1820 W. Ontario Street, Philadelphia 40, Pennsylvania (Batteries)

EDWARD FRANCIS HENSLEY, The Dow Chemical Company, mailing add.: Route 2, Box 381 B, Concord, California (Organic Electrochemistry, Corrosion, and Alkali and Chlorine)

JOHN BRANDT HOLLOPETRE, General Electric Company, mailing add.: 1202 Worton Boulevard, Cleveland 24, Ohio (Electronics)

ANDREW JOSEPH HUMPHREY, Carbide & Carbon Chemicals Corporation, mailing add.: Route #3, Concord, Tennessee (Electronics and Industrial Electrolytic)

HUGH KENNETH LANCASTER, mailing add.: Cia Minera Aguilar, Via Tres Cruces, FCCNA, Pcia de Jujuy, Argentina, South America (Electrodeposition and Electrothermic)

HENRY FRANCIS MYERS, mailing add.: Columbia Steel Company, Pittsburg Works, P. O. Box 471, Pittsburg, California (Theoretical Electrochemistry, Corrosion, and Electrodeposition)

Book Review

QUANTITATIVE ANALYSIS by W. C. Pierce and E. L. Haenisch. John Wiley & Sons, Inc. 440 Fourth Ave., New York, 16, N. Y. Third Edition, xiv plus 520 pages; 36 Figures. 6" x 9¼" (15 × 22.7 cm.) 1948. Price $3.75.

The chief changes in the third edition relative to the second are as follows: (1) A brief section on Hydrolysis from the Appendix of the second edition has been expanded to form Chapter 10 (6 pages) entitled "Complex Equilibria." The subject matter is, however, hydrolysis and not complex-formation. (2) A brief section, pp. 259–262, is now to be found in Chapter 14, on Potassium Bromate as a volumetric oxidant. (3) A new Chapter, 19, on Colloids and the Formation and Properties of Precipitates has been constructed by expanding a portion of Chapter 17 of the second edition. (4) Chapter 20 (4 pages) has been added on A Summary of Errors in Gravimetric Analysis. (5) In Chapter 21, Gravimetric Analysis of Simple Mixtures, a brief section on Organic Reagents has been added (pp. 402–403). (6) The chapter on Colorimetry is not included in the third edition. (7) The convention regarding the sign of electrode potentials has been shifted to the standard reduction potential basis.

Much of the expansion, i.e. 520 pages vs. 462 in the preceding edition, is due to the foregoing changes, and also to the inclusion of more problems and numerical illustrations; in addition the modified sections tend to a more detailed manner of presentation. Rather few changes were noted in illustrations, laboratory work or theoretical sections.

Some misleading statements persist in spite of the revision. A few samples are: Constituents are referred to in a number of instances where components are implied, pp. 1, 198. On p. 203 a misleading presentation is given of the concept of the equivalent weight of a substance in an oxidation-reduction process. A logical deduction from the statement as written might be that the equivalent weight of arsenious oxide is ½ rather than the correct value ¼ of the molecular weight, since arsenite ion loses two electrons in the titration process. On p. 206 the term "valence number" is used rather than the more generally used and less confusing term, oxidation number. On p. 218 a number of incomplete ionic equations are written in the confusing form $Fe^{++} = Fe^{+++}$, $U^{++++} = UO_2^{++}$, etc. etc. The style is rather colloquial in many places; for example, on p. 3 occurs the advice: "You should at all times be clean and neat in the laboratory."

As a whole this edition has remained very conservative both as to theory and experiments, which are limited to titrations, and gravimetric determinations. Rather few references to original literature are included, and very few of these of recent origin. The text gives little intimation that there might be many interesting techniques of analysis other than titration or gravimetric determination.

N. HOWELL FURMAN

Volumes Available

The Society has been notified that Dr. O. L. Kowalke has a complete set of the TRANSACTIONS, with three decennial indexes, for sale. Those who are interested may write to Dr. Kowalke at the Chemical Engineering Building, University of Wisconsin, Madison 6, Wisconsin.

NACE Announces Publications

Announcement has been made that the fourth issue of the "Directory of The American Coordinating Committee on Corrosion," published in October, 1947, is now available from the National Association of Corrosion Engineers, 905 Southern Standard Building, Houston 2, Texas.

This Directory lists the names, addresses, and fields of special endeavor of many of the principal corrosion workers in the United States and Canada. There is a cross-index system so arranged that the name and address of a specialist in some particular phase of corrosion, may readily be found. The Directory consists of four parts: Section I, a subject index; Section II, an alphabetical index of individuals including addresses; Section III, an alphabetical index of organizations and companies; and Section IV, a numerical serial number listing of individuals. Section I is an alphabetical listing of corrosion subjects, under each of which are given the reference numbers of authors (listed in Section IV) who have contributed to each of the subjects listed. Also, each corrosion subject is given a marginal reference number that is used to indicate the corrosion subject on which each individual (listed in Section II) has contributed.

Although the Directory was compiled and published by the American Coordinating Committee on Corrosion, through cooperative arrangements made between the ACCC and NACE, it is being offered for sale by the National Association of Corrosion Engineers at $2.00 per copy, the price determined by the ACCC.

The National Association of Corrosion Engineers has also recently announced publication of "Bibliographic Survey of Corrosion— 1945," by Robert D. Misch, James T. Waber, and Hugh J. McDonald, all of the Corrosion Research Laboratory, Illinois Institute of of Technology, Chicago, Illinois. Containing 129 pages, the cost of the book to members of NACE is $4.00; to others, $5.00.

This volume contains approximately 1100 references to published articles relating to corrosion, and 170 references to patents that appeared from January, 1945, to February, 1946, inclusive, in the following publications: *Chemical Abstracts*, *Corrosion*, *Corrosion and Material Protection*, *Engineering Index*, *Industrial Arts Index*, and *Metals Review*.

The abstracts are divided into two classes, general material and patents. Each class is divided into nine main groups as follows: (1) types of attack, (2) investigations in corrosion, (3) effects of specific media, (4) effects in specific equipment, (5) resistance of materials, (6) methods of prevention, (7) coatings, (8) removal of corrosion products, and (9) general and miscellaneous considerations.

The next volume of abstracts is now being planned to contain references to corrosion literature published in 1946 and 1947, with subsequent volumes for each year as abstracts are reviewed, assembled, and edited for publication.

Recent Publications of National Bureau of Standards

Copies of the following publications of the National Bureau of Standards may be obtained at listed prices from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

Table and Mollier chart for ammonia below −60°F., Cyril H. Meyers, 3 pp., 10 cents (C472).

This paper contains a table of thermodynamic properties of saturated ammonia vapor and liquid below −60°F., and a Mollier chart for saturated and for superheated ammonia vapor covering the pressure range 0.8 to 5 lb. per sq. in.

Electrode function (pH response of the soda-silica glasses), Gerald F. Rynders, Oscar H. Grauer, and Donald Hubbard, 6 pp., 10 cents (RP1923).

A series of soda-silica glasses was studied for durability, hygoscopicity, glass electrode function, and apparent response to (Na+). Depending on the percentage of silica, these glasses show three distinct regions of durability characteristics at pH 4.6.

Concentration of isotopes of mercury in countercurrent molecular stills, Samuel L. Madorsky, Paul Bradt, and Sidney Straus, 6 pp., 10 cents (RP1918).

Mercury 204 was concentrated by refluxing in countercurrent molecular stills. Two glass stills, with heater and cooler outside the distillation columns, and one still, consisting of a glass column heated externally and a stainless-steel cooler placed concentrically inside the column, were used. Mass-spectrometer analyses of isotope ratios of the mercury-

isotope concentrates were in good agreement with density determinations.

Thickness of inhibiting films on glass electrode surfaces, Donald Hubbard and Gerald F. Rynders, 6 pp., 10 cents (RP1915).

The glass electrode gave conspicuous voltage departures (errors) and alternations (swelling) of the surface that were just detectable by the interferometer. The inhibiting effect of films of electric conductors, such as metallic silver, is qualitatively compared with the inhibiting effect of films prepared from electric nonconductors.

Mass spectrometric investigations of the thermal decomposition of polymers, Leo A. Wall, 8 pp., 10 cents (RP1928).

Application of the mass spectrometer to the study of the thermal decomposition of polymers.

Mining and Metallurgical Congress, July, 1949

The Fourth Empire Mining and Metallurgical Congress, convened by the Empire Council of Mining and Metallurgical Institutions, will be held in Great Britain from July 9 to 23, 1949.

The chief object of the Congress is to afford an opportunity for scientists, engineers, and others concerned with the mining and metallurgical industries to meet and discuss technical progress and problems, including the development of the mineral resources of the Commonwealth.

The program will be divided as follows:

July 9–12, London. Inaugural Meeting, Government Reception, Banquet, and some excursions.

July 13–17, Oxford. Technical Sessions. The main subjects for discussion will be: Mineral Resources of the Commonwealth, Modern Methods of Prospecting, Problems Relative to Workers in Mines, Petroleum, Coal, Trends in Mineral Dressing, and Metallurgy and Metallurgical Industries.

July 18–23, Excursions. Visits will be made to collieries, iron and steel works, hydro-electric schemes, shipbuilding yards, and other places of both technical and historical interest.

Further information may be obtained by writing to: The Joint General Secretaries, Fourth Empire Mining and Metallurgical Congress, 436, Salisbury House, Finsbury Circus, London, E. C. 2.

Jet Propulsion Fellowships

Six $2,000 Jet Propulsion Fellowships are to be awarded annually by the Daniel and Florence Guggenheim Foundation, for postgraduate study at the Daniel and Florence Guggenheim Jet Propulsion Centers, established in 1948, at Princeton University and California Institute of Technology.

Three of the fellowships are for study at Princeton and three for study at California. The applicant is asked to state which of these universities he would prefer to attend, and whether he would accept appointment in either.

The first fellowships are available in the spring of 1949, for the academic year beginning in the fall of 1949. For most favorable consideration, applications should be received by March 1, 1949, though applications will be received until June 1, providing the fellowships have not all been filled by that time.

The purpose of these fellowships is to select and train outstanding men for basic research and leadership in the future development of rockets and jet propulsion.

Application forms have been sent to presidents and deans of engineering and technical colleges, heads of engineering organizations, and Army, Navy, and Air Force units engaged in this type of work. If not available from these sources, candidates should write direct to The Daniel and Florence Guggenheim Foundation, 120 Broadway, New York 5, N. Y.

Employment Situations

Please address replies to box shown, c/o The Electrochemical Society, Inc., 235 W. 102nd St., New York 25, N. Y.

Positions Available

RECENT GRADUATE, Chemical Engineer or Metallurgist, for supervised research and development for electrolytic metals refining plant. Training in electrochemistry and general knowledge of nonferrous metallurgy essential. Submit résumé and salary requirements. *Reply to Box A-207.*

RECENT GRADUATE, trained in the modern advances in physical chemistry and familiar with electrochemical processes; ion exchange resins; absorption phenomena; etc. Large progressive chemical metallurgical corporation of the Middle West. *Reply to Box A-208.*

CHEMICAL ENGINEER for development

work in electronics and corrosion fields. Three to five years' industrial experience in electrochemical development or production required. Large chemical industry in the Southwest. *Reply to Box A-209.*

RESEARCH METALLURGIST, Pacific Coast Area, for research on materials and fabrication of chemical process equipment. Prefer Ph.D. in physical metallurgy with several years' experience. *Reply to Box A-210.*

Positions Wanted

ELECTROCHEMIST, CH.E. with eighteen years' extensive experience in many phases of electrodeposition, electroforming, metal finishing, etching, and related fields. Plant layout, installation development, research. Wide consulting background. Several outstanding developments in bright metal and alloy gold plating. *Reply to Box 327.*

POWDER METALLURGIST, graduate chemical engineer, 35, married, 13 years' diversified experience in research, development, production in impregnated diamond tools, synthetic sapphire, cemented carbides, iron powder metallurgy, desires responsible position with progressive organization, preferably in diamond tool or in high temperature metal-ceramic field. *Reply to Box 328.*

ELECTROCHEMICAL ENGINEER, many years' experience in the production of a wide variety of chemical and electrochemical products. Expert in electrolytic alkali and chlorates. Ph.D. of Columbia 1925; of Chinese birth; speaks English fluently. Desires position in electrochemical engineering. *Reply to Box 329.*

Recent Patents

Selected for electrochemists by Fred. W. Dodson, Chairman of the Patent Committee, from the Official Gazette.

November 9, 1948

Blumenthal, S., 2,453,618, Mechanical Seal for Selenium Rectifier Cells.

Marisic, M. M., and Rutledge, T. F., 2,453,668, Electrolytic Method for the Production of Porous, Catalytic Metal.

November 16, 1948

Hill, H. W. and Dance, E. L., 2,453,691, Method of Making Ethyl Chloride.

Conn, J. B. and van de Kamp, J., 2,453,701, Process for Electrolytic Oxidation of Quinoline to Quinolinic Acid.

Renzoni, L. S., 2,453,737, Process for Producing Modified Electronickel.

Smith, C. S., Jr., 2,453,763, Selenium Rectifier and Process for Making Same.

Snyder, E., 2,453,764, Protection of Certain Nonferrous Metal Surfaces.

Donkin, W. F., 2,453,835, Battery Handle and Hold-Down Bracket.

Grenot, L. D., 2,453,904, Electrolytic Preparation of Corrosion Testing Elements.

Galloway, C. D., 2,454,052, Storage Battery Plate Assembly.

Slayter, G., 2,454,100, Battery Plate Separator.

Ellsworth, J. T., 2,454,142, Electrolytic Recovery of Zinc.

Sparrow, H. T., 2,454,229, Thermoelectric Generator with Pilot Burner.

November 23, 1948

Fritzlen, T. L., 2,454,312, High-Strength Corrosion-Resistant Aluminum Alloy Sheets.

Byler, W. H., and Carroll, C. C., 2,454,499, X-Ray Screen.

Zingaro, P. W., 2,454,584, Hygrometer.

Quinn, G. S., 2,454,745, Method and Means for Protecting Fluorescent Coatings and the Like.

Smith, L. H., 2,454,757, Electric Space-Charge Device.

November 30, 1948

Searle, A. M., 2,454,843, Metal Rectifier.

Skinker, M. F., 2,454,846, Rectifier Stack.

Miller, C. G., 2,454,935, Continuous Wire and Strip Electro-Processing Machine.

Starkey, R. L., and Wight, K. M., 2,454,952, Measurement of Corrosive Characteristics of the Soil.

Young, G. L., 2,454,956, System for Corrosion Protection.

Loveless, D. L., 2,455,073, Production of Stainless Steel.

Loveless, D. L., 2,455,074, Production of Stainless Steel.

Holmes, C. E., 2,455,176, Selenium Rectifier Element.

December 7, 1948

Franchi, F. A. R., 2,455,411, Process for the Treatment of Iron in Order to Obtain a Clean Metallic Surface.

Froelich, H. C., and Margolis, J. M., 2,455,413, Calcium Phosphate Phosphor.

Froelich, H. C., and Margolis, J. M., 2,455,414, Aluminum Phosphate Phosphor.

Froelich, H. C., 2,455,415, Ultraviolet

Emitting Magnesium Pyrophosphate Phosphor.
Haun, J. C., and Simpson, R., 2,455,485, Austenitic Stainless Steel.
Brown, H., 2,455,554, Electrodeposition of Copper.
Brown, H., 2,455,555, Electrodeposition of Nickel from an Acid Bath.
Bendix, G. H., 2,455,726, Method for Electrolytic Stripping and Determination of Plating Metal.
Crise, G. W., 2,455,738, Electrostatic Air Filter and Circulator.

December 14, 1948

Malek, S. K., and Laing, M. R., 2,456,070, Thermoelectric Generator with Fluid Cooling.
Winter, L. L., 2,456,099, Electrode for Vacuum Discharge Apparatus.
Feller, A. M., 2,456,117, Salinity Metering System.
Cass, O. W., 2,456,173, Photochlorination of Acetylene.
Grube, W. L., 2,456,185, Electroplating Apparatus.
Jacobs, J. H., and Yarroll, W. H., 2,456,196, Electrolytic Cell for Recovering Magnanese.
Berg, C., and Berg, M., 2,456,246, Battery Gland for Terminals or Vents.
Horsfield, B., 2,456,279, Apparatus for Electrostatic Separation of Material Particles.
Hyner, J., 2,456,281, Removing Incrustations from Lead Anodes Used for Chromium Plating.
Buck, M. P., 2,456,370, Process for Producing Electrodeposited Nickel Strip Containing Boron.
Clark, F. M., 2,456,381, Electric Capacitor.
Alvear, V., 2,456,477, Electric Battery Improvement.

December 21, 1948

van Geel, W. C., 2,456,758, Blocking-Layer Electrode System.
Williams, P. D., 2,456,761, Rugged Cathode.
Samuelson, W. H. E., 2,456,795, Cathode Sputtering Apparatus for Coating Oscillator Plates.
Smiley, L. D., and Lansing, E. S., 2,456,897, Electrolytic Clarification Apparatus.
Brasch, A., 2,456,909, Method of Sterilizing and Preserving.
De Long, H. K., 2,456,931, Anodizing Magnesium Alloys.
Frostick, H. G., 2,456,936 Regulator System.
Longini, R. L., 2,456,968, Process for Outgassing Photocells Containing Antimony.
Medlar, L. A., 2,456,978, Battery Charger.
Wise, E. M., and Vines, R. F., 2,457,021, Palladium Plating.
Leverenz, H. W., 2,457,054, Luminescent Materials for Electric Discharge Devices.
Loveless, D. L., 2,457,055, Production of Stainless Steel.
McQuire, R. C., 2,457,059, Method for Bonding a Nickel Electrodeposit to a Nickel Surface.
McQuire, R. C., 2,457,060, Method for Bonding a Nickel Electrodeposit to a Nickel Surface.
McQuire, R. C., 2,457,061, Method for Bonding a Nickel Electrodeposit to a Nickel Surface.

December 28, 1948

Hoffman, R. A., 2,457,152, Electrodepositing Composition and Bath.
Miller, A. J., and Fleisher, J. W., 2,457,169, Method of Manufacturing of Rectifier Elements.
Stateman, M. J., 2,457,186, Method of Electroforming Rectifier Elements.
Herbert, W. S., and Francis, H. T., 2,457,234, Apparatus for Electrolytically Determining the Thickness of Metal Coatings.
Sandusky, J., 2,457,322, Electrolyte Level Control Device for Storage Batteries.
Van Ornum, D. G., 2,457,510, Electroplating Apparatus.
Atlee, Z. J., 2,457,626, Grid Construction.
Metten, H., and Koury, F., 2,457,781, Ray Counter.

January 4, 1949

Feild, A. L., Reissue 23,068, Electrolytic Polishing of Stainless Steel.
Feild, A. L., Reissue 23,069, Electrolytic Polishing of Stainless Steel.
Ellis, G. B., 2,457,810, Sealing Device for Dry Cells.
Spiegelberg, H., 2,457,933, Process for Electrolytic Reduction of Pentonic Acid Lactones.
Malmberg, T. G., 2,458,013, Selenium Rectifier Element and Method of Manufacturing Same.
Hemker, H. W., and Eppink, D. L., 2,458,073, Coating Magnesium and Magnesium Alloys.
Jones, R. R., 2,458,272, Electric Splicing Device.
Unschuld, H. M., 2,458,320, Flow Tube.

Feature Section

The Profession of Electrochemistry

II. Government Opportunities for the Electrochemist

*William Blum**

The outstanding scientific feature of World War II was probably not the development of new principles, such as were illustrated and publicized by the atomic bomb, but the realization by military and civilian leaders, and by the general public, that both military and industrial supremacy depend upon the extension and application of knowledge in every field of science. This intimate relation of industrial and military uses of science makes it difficult at times to decide just which results of research should be "classified" and which should be freely published. Fortunately, the present policy is to encourage the dissemination of scientific information and to classify only direct military applications.

The recognition of the value of science by the military agencies has led them to support researches in universities and other institutions upon fundamental problems of science, many of which have no apparent relation to military activities. In consequence, the Government is, in effect, employing a large number of scientists who are engaged on these projects, since their salaries are paid from grants of public funds. These activities, and the present demands from industry for qualified scientists, whose supply is now inadequate, add to the difficulty of obtaining and retaining scientists for work in Government establishments.

Like other branches of science, electrochemistry has found many new or expanded applications in both industry and armament, with a resultant increased demand for persons qualified in this field. In addition to the obvious direct applications of electrochemistry in electroplating and electrorefining, primary and secondary batteries, electric furnaces, and protection of metals against corrosion, there are numerous less direct demands for electrochemical knowledge and experience.

It may be appropriate and mutually advantageous to discuss briefly the factors that may influence persons in this field to accept Government positions. It is not necessary to list the positions, salaries, and examinations, upon which detailed and up-to-date information may

WILLIAM BLUM

be secured from the U. S. Civil Service Commission. This agency will supply data regarding both general examinations and those conducted by or for specific agencies, e.g., branches of the War and Navy Departments, the Atomic Energy Commission, the National Bureau of Standards, the National Institute of Health, and the Departments of Agriculture and Interior.

For younger men and women with a B.S. or M.S. degree in science, Government service offers an opportunity to gain research experience in many special fields, including electrochemistry. It may therefore serve as a valuable training school. This indirect pedagogical feature is augmented by numerous advanced classes (both in-hours and out-of-

* Chemist, National Bureau of Standards.

hours), taught by specialists, and accepted for post-graduate credit by many educational institutions. Even though a large proportion of these younger Government scientists "graduate" within a few years into industry or teaching, a certain number conclude that the advantages of Government service appeal sufficiently to their interests to lead them to make a career with the Government.

In the normal development of Governmental research, vacancies that occur are filled so far as possible by advancement of those employees whose education, experience, and ability qualify them for increased responsibilities. In certain cases, and especially when activities are expanded, or new projects are undertaken, it is necessary to seek outside for personnel qualified in special fields, e.g., those with a Ph.D. degree and from 5 to 10 years experience in research. In general, it is not now possible for the Government to compete with the salaries offered by industry to such persons. However, it is to be hoped that persons will be attracted to Government service who desire to specialize more freely than is sometimes possible in industry, or those who desire greater scientific recognition of their achievements, or who feel an urge to render public service.

Sound, progressive scientific researches, e.g., in electrochemistry, are essential if this country is to maintain a pre-eminent military and industrial position. The generous response of scientists to meet the needs of the Government in time of war justifies the hope that electrochemists who are interested in research will give careful consideration to openings in the Government service.

Some Society Committees and Their Functions

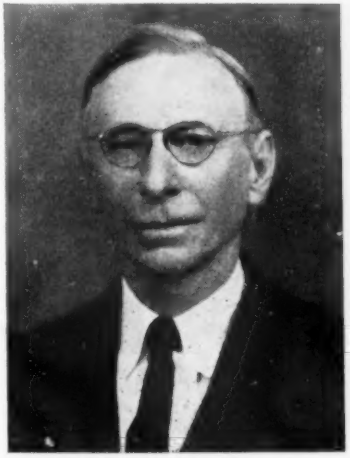
*William Cabler Moore**

The business of an organization as small relatively as The Electrochemical Society is, nevertheless, very considerable in amount and varied in nature. It is carried on by the officers, by the Assistant Secretary and his staff, by the Editorial Staff, the Editorial Board, the Board of Directors, and by various committees.

Of the latter, two at least are well known to most of our members—the Publication Committee and the Membership Committee. These have been standing committees of the Society for many years, and their chairmen have long been members of the Board of Directors.

Ways and Means Committee

Less well known perhaps, is the Ways and Means Committee. Organized in the summer of 1946 to study proposals made by President Kirkpatrick's Committee on Future Activities (set up in 1944), the value of a disinterested impartial group of advisers to the Board of Directors and President of the Society soon became apparent. At the annual meeting in 1948 this committee became a part of the permanent organization of the Society. It is unique in that it is the only committee which provides definitely



WILLIAM CABLER MOORE

* Research Chemist, U. S. Industrial Chemicals Incorporated, Stamford, Conn.

for making use of the talents of Past Presidents, since the Constitution requires that its membership must include at least two of these "elder statesmen." Moreover, by including active members who have not held elective offices, it may easily become an excellent training ground for officers-to-be, and for future members of the Society's directorate.

While a great deal of its work is performed by the committee as a whole while in session, many of the problems handed to it by the Board of Directors are "farmed out" to sub-committees. The chairman of each of these sub-committees must, of necessity, be a member of the Ways and Means Committee, but he is given a free hand in selecting the other members of his committee, none of whom generally are members of the Ways and Means Committee or of the Board of Directors. This method of "spreading the work" of the Society is already having an effect in stimulating interest in the Society.

Constitution and By-laws Committee

When the Ways and Means Committee began its study of the Society's organization, it became evident that amendments would have to be made in the Constitution and in the By-laws, in order to effect the changes which seemed necessary to implement the suggestions of the earlier Committee on Future Activities. These were received from members at large when they replied to the questionnaire sent out early in 1947.

The present writer was appointed head of the Sub-committee on Amendments to the Constitution and By-laws, and he asked for and obtained the assistance of Messrs. R. L. Baldwin, C. A. Crowley, A. Kenneth Graham, and R. B. Hammond in handling this matter. Although over ninety per cent of the work of this committee was accomplished by correspondence, the job was done so well that the main items to be covered in the revised Constitution were ready by January 1, 1948, and all were in the hands of the Board of Directors by February 1, as provided by the Constitution. In those instances involving changes in the By-laws, the proposed amendments were in the hands of the Board long before the time for voting had arrived.

Division By-laws Committee

With the work of revamping the Constitution and By-laws of the Society well in hand, it next seemed desirable to standardize the by-laws of the Divisions. Accordingly a new Division By-laws Committee was set up as a sub-committee of the Ways and Means Committee, with the division secretaries as the active working members.

The first meeting of this committee brought some interesting facts to light. The officers of one division were able to produce only one copy of any by-laws at all, and these had been adopted more than 20 years ago. On the other hand, the chairman of the committee had in his possession a completely revised set of that division's by-laws which had been adopted and approved by the division and by the Society's directors many years later.

It soon developed that while there must of necessity be some differences in the by-laws of the various divisions, nearly all of them contain provisions which are irrelevant or which are incompatible with the Society's regulations. In order to remedy this situation, the by-laws of the various divisions have to be compared and altered to fit definite standards; and this takes considerable time since it can best be done in actual working sessions of the committee.

Local Section Advisory Committee

For many years, the officers of the Society have sought to find some easy way to give the sections of the Society direct representation on the Board of Directors without increasing the Board to an unwieldy size. In the summer of 1947, President Heise found the solution to this problem. He suggested that each section should be empowered to send, to every national meeting of the Society, two delegates to a Local Section Advisory Committee, to be set up as a sub-committee of the Ways and Means Committee. The immediate Past President of the Society, who was a member of the Ways and Means Committee, was appointed chairman of this sub-committee and the sections were thus automatically given representation on the Board.

The first meeting of the Local Section Committee was held at Boston in the fall of 1947. Its success was so immediate that it was decided to set it up as a regular committee of the Society, on the same basis as the Membership and Publication Committees, with the chairman to be appointed by the Society's

President and to become thereby a member of the Board of Directors. This proposal was adopted when the revised Constitution of the Society was ratified by the mail vote of the Society's membership in the summer of 1948.

Operating at New York Convention

All of these committees met at the New York Convention of the Society in October, 1948. Important topics considered by the Ways and Means Committee were: formulation of a definite policy regarding meeting places for National Conventions of the Society; advisability of charging an initiation fee for new members; and recommendations to the Board as to prices to be charged for bound volumes of the TRANSACTIONS for the calendar year of 1949.

The Constitution and By-laws Committee held a brief meeting at which all the members except Past President Baldwin were present. Since there are some pending changes to be made in the By-laws, and possibly in the Constitution, this meeting was adjourned subject to call by the chairman for further work by correspondence.

Although the attendance was small, the Division By-laws Committee put in some good work on the development of a standard set of by-laws. This committee will hold its next meeting in connection with the Convention in Philadelphia in May, 1949.

The Local Section Advisory Committee held a large and enthusiastic meeting at which delegates from nearly all the sections were present. After electing Dr. F. A. Lowenheim of the Metropolitan Section as its secretary, those present approved the report of a sub-committee headed by Dr. E. G. Enck of the Philadelphia Section, offering a model set of by-laws for consideration by the officers of the individual sections. It was learned that some sections have never had any by-laws, but copies of the model have been distributed to every section and it is hoped that soon many of these important charters will be submitted to the Society's Directors for their approval. The meeting then resolved itself into a spirited round table discussion of the problems of the sections, chiefly those dealing with meeting places, finances and the securing of high caliber speakers for local meetings.

Since the isolated section in a small community, the medium sized section in a highly industrialized city, and the large sections in metropolitan centers each have specific program difficulties peculiar to their geographic locations, a committee composed of R. B. Hammond, Chairman (Niagara Falls Section), Howard Hauser (Midland Section), and Sherlock Swann, Jr. (Chicago Section), was appointed to study "Cooperation in Program Planning." These gentlemen are actively at work on their assigned task, and it is expected that the report to be submitted at the Philadelphia Meeting in May, 1949, will be full of helpful suggestions which may be used by local section officers in planning their 1949–1950 activities.

Plan now to attend

The 95th Meeting of The Electrochemical Society

at the Benjamin Franklin Hotel in Philadelphia
May 4, 5, 6, and 7, 1949

Sessions on

Luminescence, Rare Metals, and Theoretical Electrochemistry

Technical Notes and Reviews

Surface Preparation by Electropolishing

*Charles L. Faust**

Introduction

This paper deals with the surface preparation of metals by a method that introduces no mechanical work or physical surface damage. Electropolishing is the subject of many references in the technical literature. Within the limited confines of this paper, many pertinent references will, of necessity, have to be omitted. Reference is made, herein, to a number of articles for guidance of the reader who may desire to investigate surface reactions and wants to know where to turn for methods of preparation by electropolishing and for information on results attainable.

In electropolishing, the outermost skin of a metal is removed by anodic dissolution in an acid or alkaline electrolyte. The composition of the electrolyte is based on the electrochemical activity of the metal and on the solubility of its salts (and of the salts of any alloying metals). The anode products in reaction with the electrolyte form a film immediately next to the metal surface. This film differs from the electrolyte and has greater resistivity.

One or both of two types of anode film are known to be present during electropolishing: (a) a viscous (or gelatinous) liquid film consisting of a saturated (or super-saturated) solution of the products of anodic dissolution; or (b), a gas blanket. Most generally, both types of film are present simultaneously. The appearance of the anode surface is dependent on the character of these two films, and, under proper conditions, becomes smooth and brilliant.

Owing to the presence of these "essential films," smoothening is accomplished by a selective attack, and brightening is accomplished because, in other respects, the attack is uniform and nonselective. To explain the selective action, Jacquet (1) attributes particular importance to the liquid film, which, electrochemically, is considered a "diffusion layer." The appearance of the "layer" coincides directly with an increase in internal resistance of the electrolytic cell, causing a marked rise in voltage and a drop in current. The liquid film does not closely conform to the contour of the metal surface, but has a rectilinear margin of such nature that its thickness is less at relief than at depressed regions. Schematically, this is illustrated in Fig. 1. In consequence of

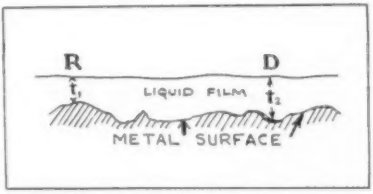


FIG. 1. Schematic sketch showing liquid film on a metal surface under electropolishing conditions.

the unequal thickness, the resistance drop through the film is greater at "t_1" than at "t_2," and anodic dissolution is more rapid at "R" than at "D." This results in disappearance of the roughness, and produces the polishing effect.

This simple explanation does not account for the observations that: (a) the recessed surface at "D" becomes brilliant because of a "micropolishing" effect; (b) electropolishing is known to take place under conditions where the liquid film is too thin to account for the electrical resistance effect; and (c) electropolishing is known to take place when the heterogeneous metal structure presents crystal faces having different activities for dissolution.

The gaseous film probably accounts for situations (a) and (b), since it causes greater insulation and, also, introduces an agitation effect within the liquid film. With gas-film predominance, surface smoothness increases and brilliance decreases. With liquid-film predominance, the reverse takes place. The relationship between gas and liquid films has been described by Berger (2) in his discussion of industrial electropolishing of brass. The anode finish may be most easily con-

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trolled when the film is predominantly liquid, whereas control is virtually impossible when it is gaseous. On the other hand, the finish obtained with gas-film conditions is less susceptible to variations. The electrolyte forming a liquid film will be more limited in application to metals having duplex or multiplex structure; because anode constituents which are insoluble or only slightly soluble will precipitate in the film to change its viscosity and resistivity. For example, with brass and orthophosphoric acid electrolyte forms an anodic film predominantly gaseous, and a chromic acid electrolyte forms a film essentially consisting of a highly concentrated solution of dissolution products from the anode. A phosphoric-chromic acid electrolyte offers a compromise that is highly satisfactory for laboratory or industrial (3) electropolishing of brass.

From these brief considerations, the general conclusion can be drawn that electropolishing takes place most suitably under conditions such that the products of anodic dissolution form a viscous liquid film at a rate just equal to its disappearance into the body of the electrolyte by diffusion and by the action of stirring caused by gas discharge. These conditions are met by: very concentrated acid or alkaline aqueous electrolytes in which the metal dissolves by complex ion formation or by supersaturation; less concentrated aqueous solutions in which solubility is decreased and viscosity is increased by organic agents; and in relatively dilute solutions for which the primary salt from anodic dissolution is water-insoluble, but is soluble in the solution because of complex ion formation. Cyanide and pyrophosphate solutions are examples of this latter type.

Accepting a hypothesis in line with these comments (4), Der Mateosian (5) took the view that electropolishing would prevail if the tendency of a metal to go into solution is reduced as low as possible so as to exaggerate relatively any differential effect due to the film covering the peaks and hollows. His objective was to combine reagents so that each performs only one of the functions required in electropolishing baths, but the mixed reagents provide for all necessary functions by combined effect.

For a given metal and selected electrolyte, the temperature and the anode current density are important factors in determining the electropolishing result. The temperature affects the viscosity, resistivity, and diffusion of the liquid film, as well as the solubility of the products of anodic dissolution in it. The current density determines the maximum rate at which the metal can enter the solution, according to Faraday's law.

The actual rate (or current efficiency of metal dissolution) depends on the combination of the other operating factors, such as temperature, solubility, diffusion, stirring effects, etc. Thus, in developing any electropolishing application, all of these factors have to be considered individually and collectively in finding the optimum conditions for producing the desired result.

Owing to the polarization effects of the liquid and gas film, metals usually dissolve in the highest valence during electropolishing; yet, there are exceptions such as cyanide solutions. In addition, the successful electrolytes involve anions having a relatively large volume and small charge, such as: dihydrogen orthophosphate; trihydrogen pyrophosphate; acetate; glycolate; perchlorate; complex cyanides; acid sulfate; alkali complexes, such as zincate; fluosulfonate; citrate; and tartrate.

Anodic polarization, even to the extent of passivity, is not alone sufficient for causing electropolishing. Metallic dissolution must take place in the viscous or gas film. Elmore (6) accounts for electropolishing on the basis of diffusion by which the dissolved metal leaves the vicinity of the anode, and, after a time, the metal concentration in the anode film reaches the solubility limit, which is the same as in the electrolyte. Assumptions are based on Jacquet's methods for electropolishing without gas discharge; i.e., under conditions corresponding to portion DE of the curve in Fig. 2.

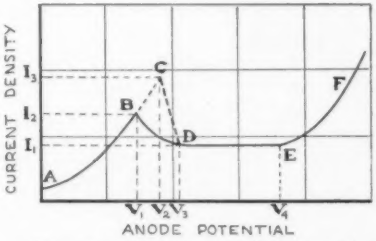

FIG. 2. Schematic drawing of a plot of current vs. anode potential in electropolishing.

Electropolishing solutions have been

investigated by measuring and plotting curves for current vs. voltage. Several different types of such curves are possible, depending upon the metal, the solution composition, the temperature, and the agitation. Therefore, no single form for a curve can be used for predicting electropoling conditions. Fig. 2 shows several relationships between current and voltage.

For a given metal in a selected electrolyte, the current will increase according to the line ABCDEF, as the anode potential increases. In one type of solution, electropolishing will take place at I_1, at voltages V_3 to V_4, i.e., along the DE branch of the line. With a different metal and another solution, the general plot will be like ABCDEF, but electropolishing will be under conditions represented by region BCD, involving a periodic fluctuation in voltage in the range, V_2 to V_3, with a corresponding fluctuation in current between I_2 and I_1. Or, there will be periodicity with a different set of voltage-current ranges within the limits of the region, BCD. A third and different metal and electrolyte might have a curve entirely like the branch EF, with no polarization effects comparable to those producing conditions for BDEF or BCDEF, and electropolishing takes place at current above I_1 and voltage above V_4.

For examples, the first situation referred to in the preceding paragraph exists for copper in orthophosphoric acid; the second, for silver in cyanide solutions; and the third, for stainless steel in sulfuric-phosphoric acid solutions. In each of these examples, conditions can be varied to alter the shape of the current-voltage curve to one of the other forms.

The conclusion is reached that electropolishing is largely an empirical process. Nevertheless, these introductory remarks will be an aid to visualizing some of the situations to be met and believed to exist when electropolishing is accomplished. Regardless of its empirical nature, electropolishing offers special advantages in the preparation of metal surfaces.

Some Properties of Electropolished Surfaces

The outstanding achievement of electropolishing is its ability to remove metal without mechanical action of any kind. Thus, smoothening and brightening are accomplished without introducing mechanical working effects, frictional heating, fragmentary metal particles, distorted crystal structure, or stresses. The electropolished surface reveals directly, in the outermost layer, the true structural condition of the basis metal. Some electropolishing conditions superimpose a solid film of the oxide or of a salt of the metal. Such a film is thin and transparent.

Fig. 3 and 4 reveal the difference in crystal structure of the outermost surface of a mechanically polished metal and of an electropolished surface. The photomicrographs were taken at the interface region of nickel electroplate

FIG. 3. Cross section of nickel plate on metallographically polished, 18-8 type stainless steel, showing essentially structureless feature of the nickel plate due to pseudomorphic continuation of the "so-called" Beilby Layer. 500 ×.

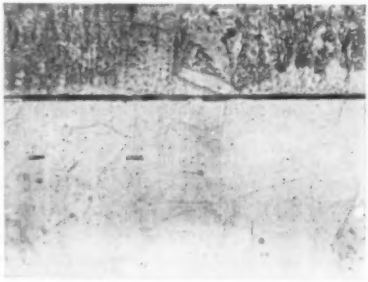

FIG. 4. Cross section of nickel plate on electropolished, 18-8 type stainless steel, showing pseudomorphic continuation of the true crystals of the stainless steel. Reveals total absence of mechanically disturbed surface on the basis metal. 500 ×.

on metallographically polished stainless steel (Fig. 3); and electropolished stainless steel (Fig. 4).

On both samples, the nickel, as it was deposited, pseudomorphically continued the crystal structure of the stainless steel surface. Fig. 4 shows the continuation of stainless steel crystals by nickel plate without interference of a superficial layer (the so-called Beilby Layer) composed of heterogeneous, very fine crystal structure resulting from the mechanical action of the metallographic burnishing. The crystal structure of this superficial layer is continued in the nickel plate, which is seen to have an entirely different structure than the nickel plate on the electropolished stainless steel. These examples show concrete evidence that the surface condition of the basis metal influences reactions occurring there.

The relationship of electropolishing to mechanical polishing relative to structure of electrodeposited metals has been observed for other combinations of plated and basis metals. Among them is copper on copper (7). The process of metal electrodeposition is subject to the activity of the basis metal surface and to any locally specific effects thereat. These same factors influence any physico-chemical or metallo-chemical reaction that takes place at a metal surface.

The structure, hardness, and other physical properties of the electrodeposited metal are influenced by the crystal size, orientation, condition of stress, and the crystal face or faces that are exposed. These same conditions can introduce undesired side reactions in a chemical process taking place at a metal surface; the percentage yield in primary product is affected, and initial corrosion rates may differ from those operative after the surface skin has disappeared.

These conditions under reference are physicochemical in nature and are, therefore, generally applicable as to possible influence on surface reactions regardless of the metal and the process involved. Thus, when interpretation is made of data involving participation by a metallic surface, the physical (and mechanical) condition of that surface must be included in the analysis.

Since electropolishing dissolves metals under conditions of anodic polarization, the concomitant formation of superficial solid coatings of oxide or salts of the metal must be considered in connection with electropolishing in any surface study. Whether there is such a coating formed depends upon the metal and the

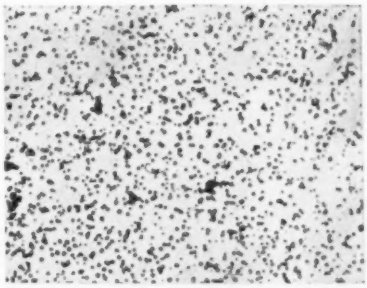

FIG. 5. Electropolished, 18-8 type stainless steel after exposure to glyceregia etchant. Owing to the presence of a "protective coating," no crystal structure is revealed; only cylindrical holes (when examined with oblique lighting) are visible, shown as pits in the photomicrograph. 100 ×. (*Iron Age*, April 11, 1940)

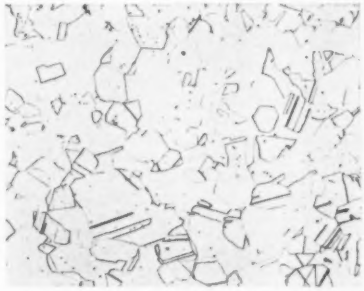

FIG. 6. Mechanically polished (metallographic specimen), 18-8 type stainless steel after exposure to glyceregia etchant for same length of time and conditions as the electropolished sample of Fig. 5. The stainless steel had been passivated in nitric acid before etching. 100 ×. (*Iron Age*, April 11, 1940)

electropolishing conditions, which also establish the nature of any such coating.

Aluminum and stainless steel are well known to the metal finishing industry as being greatly improved in corrosion resistance as a result of anodic treatment. The improvement is experimentally shown to be due to the presence of a solid film, transparent but possessing a finite thickness. The presence of such a film on electropolished stainless steel is shown by Fig. 5 and 6. Attack by

glycer-regia* etchant is seen to be different on the electropolished surface (Fig. 5) and to consist of "punching cylindrical holes" in the surface. The metallographically polished sample almost immediately revealed the structure of the stainless steel (Fig. 6). The "burnished skin" on the latter greatly influenced the structure of the nickel plate, (Fig. 3 and 4), but offered no resistance to the glycer-regia etchant.

Turning again to electrodeposition results for illustrative purposes, reference is made to copper and brass. When these metals are electropolished in chromate-containing electrolytes, they acquire a thin, transparent, "solid film," coincidentally with the brilliant, mirror-like appearance. This "solid film" is electrically conductive, as demonstrated by the fact that the mirror-like surface can be retained by electrodepositing a bright metal on it. If the bright metal is deposited on the electropolished surface, it can be easily stripped off in a continous foil of mirror-like metal.

Retaining the mirror-like quality, yet obtaining sound adhesion of the bright metal plate, introduces some interesting relationships. If the electropolished brass (or copper) is dipped into a solution of hydrochloric acid and ammonium chloride, the luster is not impaired and bright nickel plate, for example, can then be applied with excellent adhesion; but, the plated appearance will not be mirror-like. Instead, the plate will appear "frosty," because it has continued the crystal structure of the brass (not visible as electropolished), building thickness at a faster rate on some crystal faces than on others. This results in a relief effect that is comparable with the revelation of structure by metallographic etchants. Although photographs are not available to show this situation with nickel plate on brass, apt illustration can be made with Fig. 7 and 8, which are for nickel plate on electropolished and metallographically polished stainless steel. The same phenomenon is operative regardless of the metals paired in electropolishing and plating.

The interesting and practically important situation arises when the electropolished brass (or copper) is dipped in a dilute solution of sulfuric and oxalic acids (8) and, then, bright nickel plated as before. This time the mirror-like appearance is retained and, yet, the nickel is very adherent. This experimentally developed relationship has wide implications in the consideration of other metallo-chemical, surface reactions. Prior to 1940, practically all work in this field dealt with mechanically prepared metal surfaces. Undoubtedly, a number of the conclusions would be altered if the same experimental program were to be repeated with electropolished surfaces.

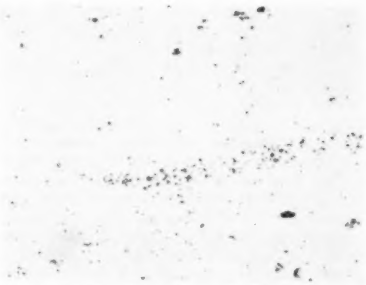

FIG. 7. Surface view of nickel plate on electropolished stainless steel (18-8 type). The nickel, by selective plate at faster rate on some crystal faces, has revealed the structure of the stainless steel, as would be expected according to Fig. 3 and 4. 100 ×. (*Iron Age*, April 11, 1940)

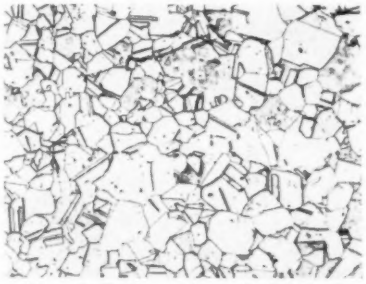

FIG. 8. Surface view of nickel plate (same plating conditions as for Fig. 7) on metallographically polished stainless steel (18-8 type). Falsely, the stainless steel appears to have no structure, because of interference by the "skin" which results from mechanical damage of the surface. 100 ×. (*Iron Age*, April 11, 1940)

10 cc. nitric acid (sp. gr. 1.42), 20–30 cc. hydrochloric acid (sp. gr. 1.17), 20 to 30 cc. glycerine. Prepare fresh just before use and do not keep in storage afterward. Throw away the used solution immediately.

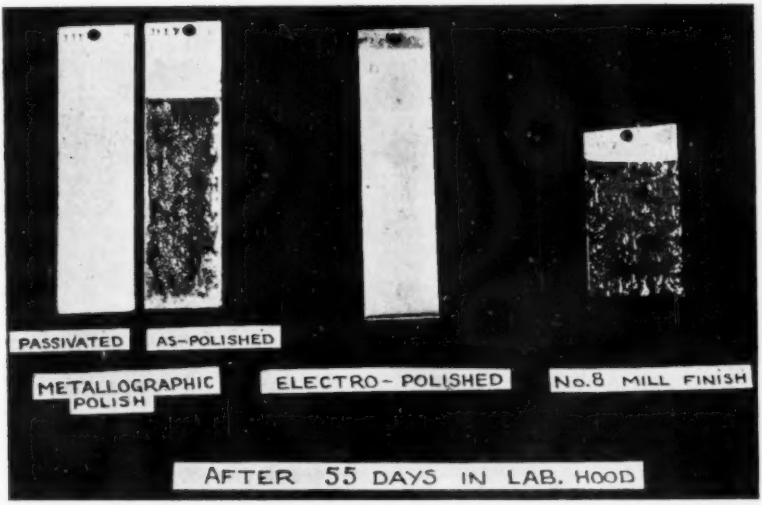

FIG. 9. Appearance of metallographically polished, electropolished, 2B mill-finished, and No. 8 mill-finished stainless steel (all 18-8 type; the first and fourth passivated in nitric acid) after 57 days of exposure in an analytical laboratory hood. The electropolished specimen remained a reasonably good mirror; the No. 8 contained a continuous coating of "red rust."

In his study of the formation and stability of oxide films, Gulbransen (9) found different film thicknesses on iron passivated in 70 per cent nitric acid relative to iron exposed to air. Electropolished metal surfaces should be included in sudies such as this. Low- and high-carbon steels and low-alloy steels, to take examples, can be electropolished to such a state of protection as to resist rusting for very long periods of time. Benefits from electropolishing are shown for stainless steel in Fig. 9.

Aluminum, electropolished in a sulfuric-phosphoric-chromic acid solution, is improved in uniformity of surface activity so that subsequent anodizing produces a more uniform and protective coating, and dye colors, if used, have a deeper and richer "tone."

Oxidation reactions, such as those which impart black oxide coatings to steel, produce more uniform color with greater luster, with less critical control being required when surface preparation is by electropolishing.

Metal surfaces can be prepared by electropolishing without the formation of an oxide or salt film. Thus, electropolishing does not always confer passivity upon a metal (10). Aluminum, zinc, and iron have been treated with such results. Thus, the "true surface" of the metal is made accessible for the study of reactions. Jacquet (1) has summarized work by numerous other investigators of surface properties.

Chemical and Electrochemical Properties

Without electropolishing, surface preparation has not been possible to represent the metal free from oxide layers, for studying the dissolution potential of such easily oxidized metals as zinc, aluminum, magnesium (11). Carefully mechanically polished aluminum dissolves in 3 per cent sodium chloride solution at −0.74 v., and the same aluminum, electropolished in perchloric-acetic acid bath and washed in acetone and absolute alcohol, dissolves at −1.20 v. The dissolution potential of zinc, measured in distilled water immediately after electropolished in orthophosphoric acid-alcohol bath and washed in anhydrous liquids, is −1.08 v. After 250 hours' exposure to moist air, the dissolution potential is −0.7 v. The authors conclude that such measurements of dissolution potentials

provide an excellent method for studying oxidation.

The oxidation of electropolished metals during subsequent exposure to air is different from that of mechanically polished metal, so that corrosion results can be quite different in water or other media. Another different result occurs if, immediately after electropolishing, an active metal like zinc is immersed in water. Corrosion figures may appear with the geometric pattern of the crystallographic structure. This has been studied by Capdecomme and Schwob (12).

From his review of the technical literature, Jacquet (1) concludes that electropolishing is the preferred method for preparing specimens to be used in corrosion studies. He cites references to investigations of aluminum (13) and of aluminum containing Al-Si and Al-Si-Fe eutectic inclusions (14). Reference is also made to the speed of oxidation of zinc (15) and to the initial corrosion of magnesium in the form of fine pits exuclsively on the twins resulting from working with a cutting tool (16). Dry oxidation of stainless steel has been found more reproducible when finishing was by electropolishing (17). This method of polishing has been found very successful in revealing structural details responsible for unusual corrosion effects, but not observable by ordinary micrography (18). Fissuring of brass alleged to be homogeneous was found due to a very small amount of beta phase, the presence of which was not suspected when mechanical polishing methods were used.

Walton (19), in studies with single crystals of aluminum, found only very small differences in solution potential with marked changes in orientation; but, different crystal faces showed different rates of attack in concentrated hydrochloric acid. A conclusion was reached that selectivity of attack was caused by resistance of individual grains instead of by differences in solution potential of individual grains.

Electrodeposition of copper at slow rate on electropolished polycrystalline copper occurred along all crystal grain boundaries, but on the flat faces of only some of the grains [Jacquet (20)]. The grains which showed only little tendency initially to take a copper plate were considered to be those with the face of vertical growth perpendicular to the general surface. This phenomenon was studied further by Leidheiser and Gwathmey (21) using single crystals of copper and electropolishing to determine the influence of crystal face on its electrochemical properties. Conditions could be selected to cause monocrystalline deposition of copper at certain regions of the single crystal and polycrystalline deposition at other regions. The initial tendency to take a plate at low current density, continuation of the orientation of the surface of the basis metal, and the smoothness of the electrodeposit are dependent upon the crystal face taking part in the process. In addition, mechanical disturbance of the crystal face can alter the result of the process, as shown by the effect of slight scratches after electropolishing, but before electrodeposition. The inability of electrodeposition to continue the orientation at certain regions of the single crystal could not be attributed to an adsorbed film left by electropolishing, so was due to other factors. The conclusion of general interest is that crystal face (as well as surrounding atmosphere and presence or absence of mechanical disturbance) has a controlling influence on the electrochemical behavior of metal surfaces. In such surface studies, it appears necessary to regard each crystal face as though it were a separate metal. Electropolishing permits evaluation of any process modifications that can be attributed to mechanical disturbance of metal surfaces.

Swann and associates (22), (23), (24), (25), (26), and (27) have recognized the importance of crystal structure on the results of electro-organic oxidation and reduction at the surface of metal in the as-cast, as-machined, as-annealed, and as-electrodeposited condition. Reaction yields and nature of the product were influenced by the character of the metal surface. In studies such as these, electropolishing should be included as a tool for surface preparation.

Physical Properties

In order to obtain correct and reproducible microhardness measurements, electropolished surfaces should be used, because mechanical polishing produces a skin hardening effect that can be as much as 30 to 40 per cent higher than the real hardness (28) and (29). Microhardness measurements can be made with sufficient accuracy and sensitivity to spot different degrees of purity. For aluminum, an impurity content of 0.004 per cent has been observed (30). The depth of metal structural disturbances caused by mechanical polishing can be

determined by electropolishing and measuring the microhardness at successively exposed levels.

Electropolished and mechanically polished surfaces can give totally different results on examination by x-ray diffraction techniques. The mechanically polished surface skin, at small angles of incidence, gives strong diffusion of x-rays. The electropolished surface has much lower diffusing power. The mechanical deformation caused by 00 emery extends about 20 microns in aluminum. Abrasion of iron with No. 2 emery causes deformation to a depth of about 60 microns (31). The iron is only very slightly disturbed by polishing for extended periods with alumina on felt.

Polishing on No. 0 emery paper is shown to cause considerable lattice distortion in zinc crystals (32). By electropolishing technique, proof was obtained that oblong bands, etching to different color in zinc or high zinc solid solution crystals, are caused by mechanical effects and are, in all probability, deformation twins.

Surface microscopy studies by x-ray diffraction (33) can include electropolishing among the preparation methods. Other investigations of electropolished surfaces by means of electrodiffraction have been reported (34), (35), and (36). For examinations such as these, the preparation of the surface is very important, and the results can be changed by the method of removal from the electropolishing solution and of washing.

Nonuniform deformation through glide planes that have slipped have been revealed by electropolishing slightly deformed brass; whereas, such markings were previously believed to be due to improper mechanical polishing (37). In study of creep and fatigue as affected by grain boundaries, Crussard (38) found electropolishing a good tool for revealing the nature of slip in polycrystalline aluminum, zinc, and magnesium.

The reflectivity of electropolished surfaces is higher than that of those produced by the most careful mechanical finishing methods (39), (40), (41), and (42).

A study of cathodic luminescence shows that mechanical polishing always causes a pollution of the surface, whereas electropolishing does not (43).

Electropolishing is a very important tool in the study of surface reactions with single crystals (44) and (45).

Electropolishing, by removing surface stresses, considerably changes thefatigue behavior of metals. Mondon's (46) experiments show that electropolishing of certain steels considerably raises the fatigue limit and aids in its measurement by reducing the scatter of experimental values. He also discusses wear of electropolished surfaces.

Other researches, reported by Russell, Gillette, and Jackson (47), show that fatigue limit of steels is generally lowered by electropolishing. This is because the customary mechanical finishing methods introduce strain-hardening and compressive stresses that increase fatigue resistance. When there is no mechanically disturbed layer, such as when very careful mechanical polishing is used, fatigue limit is the same as for electropolished steel.

If there has been heavy surface decarburization, then electropolishing, to remove such a "decarb" layer, will increase the fatigue limit.

Halut (48) discusses the application of electropolishing to mechanism parts. Because of reduced friction, electropolishing of parts in a wire-sewing machine permitted a considerable increase in speed. Electropolishing of duralumin cartridge cases improved the ease of automatic extraction without jamming caused by the rough state of the as-drawn surface.

In connection with the surfacing of one metal with an electrodeposited coating of another for use of the component in industrial service, electropolishing has an important role. This is particularly so when the "interface zone" between basis metal and electrodeposited metal will be subjected to heavy stresses during functional use. Mechanical finishing can so damage the surface of the basis metal as to make it too weak to properly support the overlay metal (49). Electropolishing as the "surface-machining operation" provides for the maximum bond strength and adhesion that can be expected.

Schaeffer (50) employed electropolishing to successfully replace an electrochemical etch in preparing steel bearing shells for receiving copper and silver liner.

Surface Smoothness

Electropolishing can greatly reduce the microroughness of metallic surfaces. According to unpublished data from Battelle Institute researches, electropolishing, to remove an average of 0.001 inch of metal from a surface having a

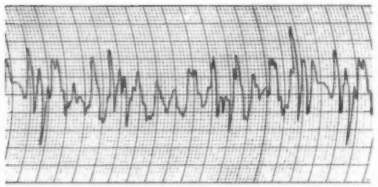

FIG. 10. Brush surface-analysis chart of commercial polish on steel ready for nickel plating. Horizontal 17 × and vertical 4000 ×.

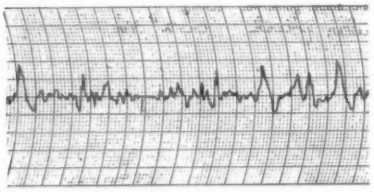

FIG. 11. Brush surface-analysis chart of 0.002 inch of bright nickel plate on commercially polished steel.

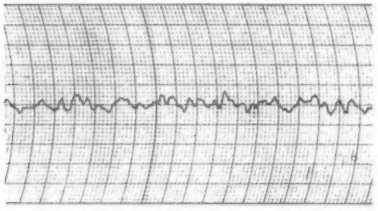

FIG. 12. Brush surface-analysis chart of 0.002 inch of bright nickel plate on commercially polished steel after mechanically buffing the nickel plate.

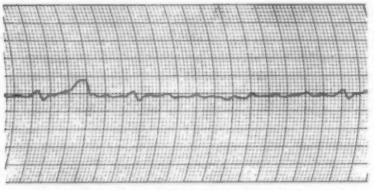

FIG. 13. Brush surface-analysis chart of 0.002 inch of bright nickel plate on commercially polished steel after electropolishing to remove an average thickness of 0.001 inch of the plate.

profilometer roughness of about 50 r.m.s., smooths this to about 25 r.m.s. Removal of another 0.001 inch of metal reduces the roughness to about 12 r.m.s., and so on. This experimental work was carried no further than an r.m.s. reading of 2 to 3. Sparks (51) reduced the surface roughness from 4 microns (after lapping) to 0.3 micron by electropolishing. Measurements were made on a profilograph. Wear characteristics of electropolished steels have been discussed by Mondon (46), who reached surface roughness as low as 0.1 micron. In tensile tests, the scatter of results was found to be less with electropolished specimens (48).

Smoothening accomplishable by electropolishing plated metal surface coatings is illustrated by Fig. 10, 11, 12 and 13.

Electropolishing Methods

No recipes are given in this paper for electropolishing. Electropolishing baths are quite specific, depending upon the principal factor under study and the kind of metal or alloy involved.

The random orientation of polycrystalline metals presents crystal faces of different activity. Such local differences are so small, relative to the electropolishing potential, that selective dissolving does not take place to cause "etching," as in the case of anodic dissolution in the absence of film formation. On the other hand, dissolution potentials can be so high for some alloy phases as to prevent electropolishing. Difficulties in this respect are encountered when certain metal-carbides, silicon-rich phases, lead-rich phases, and tin-rich phases are present. When conditions that electropolish a metal in the absence of such phases do not electropolish when they are present, a different solution must be used, and, at least, for experimental work, one can usually be found.

Some electrolytes have wider application than others. Specific methods have been described in numerous technical papers. Jacquet (1) and Zmeskal (52) have given comprehensive bibliographies. For one who is just starting in the field of electropolishing, the following references will provide helpful information. Industrial applications of electropolishing in finishing for appearances, machining, burr removal, and preparation for plating have been described by the author (53), who shows that most of

the commercially operable methods are covered by patents. Comments on industrial applications in Europe have been made by Halut and Rocquet (54).

Procedures for electropolishing in metallographic preparations (55) and for electron-microscope samples (56) offer helpful suggestion for methods of surface preparation. Where methods involve perchloric acid, precautions must be exercised. Not all articles discussing electropolishing in baths using perchloric acid mention the explosive character. Such solutions can be used with safety when the necessary handling techniques are recognized and employed.

Apparatus set-ups for laboratory electropolishing have been described (57), (58), (59), (60), and (61).

The following references will be of interest in connection with electropolishing the metals and alloys of the "iron group": carbon steels (62), (63), (64), (65), (66), and (67); cobalt (68); and stainless steels (69), (70), (71), (72), and (73).

Methods of potential interest for electropolishing non-ferrous metals are described in the following references: aluminum (74) and (75); copper (76) and (77); gold (78); silver (79), (80), and (81); tin (82); magnesium (83); tantalum (84); tungsten (85) and (86); zinc (87) and (88); copper, lead, tin and their alloys (89); brass (90) and (91); bronze (92); and leaded bronze, zinc, and magnesium (93); and review of several methods (94).

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Are You Changing Your Address?

It is important that the Secretary's office be informed of your change of address. Notice of your new address should be mailed as promptly as possible. Delivery of publications can be assured without interruption only if change of address notice is received in advance (four to six weeks if possible).

When change of address means change of position, please include this information in your notice, giving title of the position which you will have in the new organization. Other members will enjoy reading these news items in the *Journal*.

All forwarding addresses should be sent to the Electrochemical Society, Inc., 235 West 102nd Street, New York 25, N. Y.

"Give Me Liberty Or—"

Patrick Henry said "Give me liberty *or* give me *death.*" Hitler and Mussolini proclaimed"—*or* give me *security*" with emphasis upon security. Stalin today follows the same pattern—he promises, in exchange for complete subjugation to the State, old-age pensions, socialized medicine, state education, and free advice on the direction in which scientific theory and religious philosophy *must go.* For the price of a few principles like freedom of speech and exercise of the ballot, one can enjoy a "cradle to grave" paradise on earth, communist style.

There are large factions in this country (not communists) who have become enmeshed in the same dangerous trend. With good but misguided intentions, they clamor for more of so-called social legislation, for more government control of business, and for gross subsidies to agriculture and to inefficient or defunct business. The goal is security for everybody, and a shift of all planning and worrying by the individual to appropriate bureaus in Washington. Let no one be deceived—this security, like that of Stalin, is at a price.

Let's get the facts straight! First, a degree of security is both possible and desirable. A man takes out life insurance or saves a portion of his income for future contingencies—he chooses his own plan and is better for it. But when he surrenders to others his privilege to act and to think, he becomes less a man, and eventually both he and society pay the penalty.

Second, security cannot be guaranteed. No insurance company can guarantee good health or happiness. Economic security cannot be guaranteed by the government itself, as many who now draw their pensions with deflated dollars have found out.

Wherein lies security? Not in money—not in philosophies of government—not in science itself—but in the hearts and minds of men. Every worthwhile and lasting effort of men so far has been the result of clear thinking in this respect.

In the same sense, the security of The Electrochemical Society lies in its members. A member who joins only to get out of the Society what he can has little faith in a way of life that holds privilege undivorced from responsibility. And industries, too, who excuse themselves from sustaining a technical society from which they benefit support the free enterprise system by mere lip service.

In the long run, to accept privilege is to accept corresponding responsibility. If one seeks to gain for himself by avoiding responsibility, the gain, if made at all, is at the expense of privilege or liberty.

To men of vision, liberty is priceless. Accepting any commodity or promise in exchange is to move backwards in the scale of human progress and to renounce a fundamental struggle since early dawn for increasing freedom. For with greater freedom, men contribute in greater abundance, not only the necessities of life, but also beyond such needs, making possible the effective advance of science and the arts. A free society of responsible citizens can offer to everyone a wealth and security that dictators and bureaucrats are powerless to provide.

H. H. U.

Current Affairs

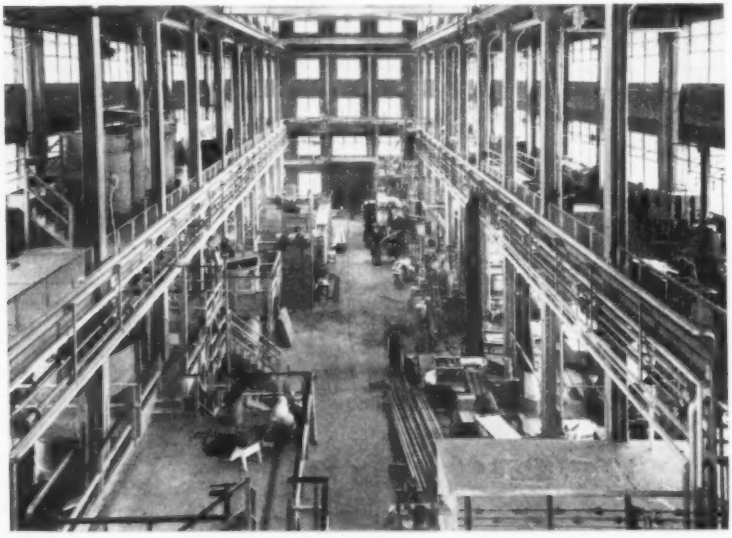
Philadelphia Program Largest in Society's History

The Philadelphia Convention, from present indications, will be the largest and one of the most important in the history of the Society. The technical program will comprise 75 papers, nearly twice as many as have been presented at any previous meeting. There will be a two-day session on Luminescence sponsored by the Electronics Division with Dr. H. C. Froelich presiding. Twenty-seven papers by leading American, English, Dutch, and Hungarian authorities will be presented. A session on Rare Metals will include twenty papers describing striking new developments in this field. Mr. E. G. Enck will preside. The Theoretical Electrochemistry Division is presenting a symposium of sixteen papers of a fundamental character by several of this country's most eminent electrochemists. In addition there will be a general session which will include twelve papers on corrosion, electrodeposition, batteries, and electroorganic chemistry.

The very large number of papers and the large attendance which they are expected to draw will require simultaneous sessions to be held. This has long been a practice of other technical societies, but it is a new venture for The Electrochemical Society. The smaller individual groups should promote more informal discussion.

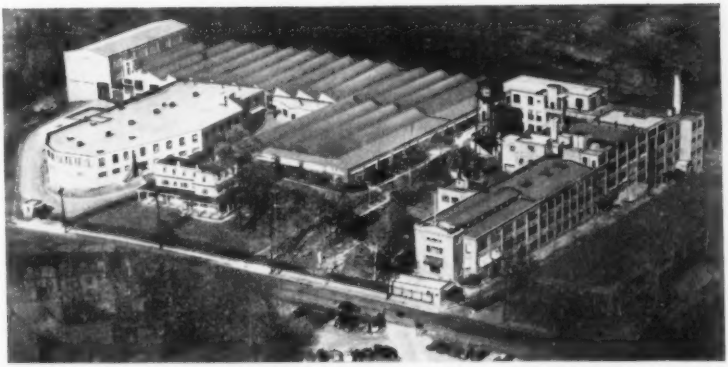
Round Table Discussions

In addition to the formal technical sessions, there will be three informal group discussions. The Electrothermic Division is sponsoring a Round Table on the subject, "Special Melting Techniques



Interior view of wing where pilot plant investigations are conducted, Eastern Regional Research Laboratory, U. S. Department of Agriculture, Wyndmoor, Pa. Included in plant trips for May 6th.

U.S.D.A. Photo by M. C. Audsley



Plant of Leeds & Northrup Company, Philadelphia, manufacturer of scientific instruments, will be a feature of Society's inspection trip on May 6th.

for Metals." Nathan E. Promisel, Bureau of Aeronautics, Navy Department, will be the moderator at this session on Saturday morning. At the same time, a second Round Table Discussion on construction materials for chlor-alkali plants will be held under the sponsorship of the Industrial Electrolytic Division. The members of the Electronics Division will meet for an informal Round Table discussion immediately following the symposium on luminescence.

Business and Committee Meetings

The Annual Business Meeting of the Society will be held at 8:45 A.M. on Thursday. At that time, the newly-elected officers will be announced. Wednesday will be given over largely to committee meetings. The Constitution and By-Laws Committee, the Publication Committee and Editorial Staff, and the Division By-Laws Committee will meet in the morning. The Local Section Advisory and the Ways and Means Committees are scheduled for the afternoon. The Board of Directors will meet after dinner.

Annual Banquet

The Annual Banquet will be held on Thursday evening, May 5th, in the Ballroom, following a reception for all the officers at 6:15 P.M. The principal event of the evening will be the Presidential Address by the retiring President, Mr. James A. Lee. Mr. Lee will also present the Young Author's Prize and the Turner Book Prize. After the conclusion of these ceremonies, there will be dancing and bridge.

Luncheons

Society luncheons have been arranged for Thursday and Friday. On Thursday, the President of the Society will speak briefly on the convention program and plans for the Society's future. At the Friday luncheon arrangements have been made for separate seating of the various divisions of the Society. This should provide an excellent opportunity for division members to renew old acquaintances and make new ones.

Friday Evening Entertainment

An informal program is planned for Friday evening. Supper will be served at 7:30 in the Ballroom and immediately thereafter there will be a program of entertainment, provided by the Local Committee, which promises fun for all in the form of a "tombola." The Editorial Staff has not been informed of the precise nature of this activity.

Plant Trips

Two plant trips are planned for Friday. In the morning, a group will travel by bus to the plant of the Leeds and Northrup Company, manufacturers of electrical measuring and recording equipment familiar to every electrochemist. After luncheon there will be a second trip, to the Research Laboratories of the Pennsylvania Salt Manufacturing Company at Whitemarsh. A visit to the Eastern Regional Research Laboratories

Pennsylvania Salt Manufacturing Company's Research Laboratories. Formerly the residence of the late E. T. Stotesbury, this 130-room mansion is now converted into a fully-equipped research and development laboratory. It will be included in the Society's plant trips on May 6th.

of the United States Department of Agriculture at Wyndmoor will complete the afternoon program.

Ladies' Program

A full program has been planned for the ladies. On Thursday there will be a reception and get-together at 11:00 A.M. followed by luncheon in the Garden Terrace of the Benjamin Franklin Hotel. In the afternoon, there will be a conducted tour through the famous Philadelphia Art Museum. The ladies are of course invited to the reception and banquet on Thursday evening.

Friday will feature an all-day trip to Longwood Gardens, on the world-renowned estate of Pierre S. du Pont. Luncheon will be provided and the only charge will be $2.50 for transportation. The ladies are invited to attend the informal supper and entertainment in the Ballroom beginning at 7:30.

Silicon Carbide Plant Opened in Quebec

A new name was recently added to the world's list of producers of silicon carbide. Electro Refractories and Alloys Corporation of Buffalo, long a user of this raw material, has formed a Canadian subsidiary, Electro Refractories and Alloys Canada Ltd. which has established a plant for the production of silicon carbide under the trade name "Electro-Carb." The new plant is at the mouth of the St. Maurice River in Cap-de-la-Madeleine, Quebec.

The new plant, which represents an investment of $475,000, was placed in production on January 4th, 1949, less than one year from the date when the site was selected. The official opening was held on January 21st at which time the directors and officers of the company welcomed the members of the Chamber of Commerce and other dignitaries of the cities of Trois Rivieres and Cap-de-la-Madeleine in an inspection trip through the new plant and a cocktail party and reception at the Chateau de Blois in Trois Rivieres. Other guests included officials of the Canadian firms which supplied equipment and services for the construction of the new plant.

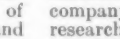
The celebration included a return banquet on the following day at which the Hon. J. Paul Beaulieu, Minister of Trade and Commerce of the Province of Quebec, delivered an address in which he stressed the unwavering adherence of Quebec to the principles of private enterprise.

The facilities of "Electro-Canada" include the main furnace building, containing two separate sets of five furnaces each, as well as storage, mixing, and charging units to serve these. There is a second large building for storage of additional materials which can thus be

laid in ahead of the long Quebec winters. The plant is served by a railroad siding and also by a dock from which waterborne shipments can be made direct to Buffalo where the manufacturing plant of the parent company is located. Other buildings include an office and service building.

The present capacity is 3000 tons of silicon carbide annually. This will be shipped exclusively to the parent company for processing and use in its refractories and other products. No present plans exist for making raw material for sale to others. The installation of considerable additional crushing and processing equpment at the parent plant was necessary to handle the new material there.

Electro Refractories was founded in 1918 and was developed in its early stages by the late Luke U. Milward. The present management is headed by President Grant S. Diamond. Carl F. Leitten and George B. Michie are Vice-Presidents in charge of Manufacturing and Sales respectively. The new plant is under General Manager R. A. Webber, who has had a background of experience at the Exolon Company of Thorold, Ontario. Plant construction was supervised by him and by E. P. Yockers, Mechanical Superintendent of the parent company. The company is distinctly research-minded; the Director of Research is G. J. Easter, who is a member of the Niagara Falls Section of The Electrochemical Society.



Uhlig Heads New Inter-Society Corrosion Committee

The National Association of Corrosion Engineers has recently organized an Inter-Society Corrosion Committee which will carry on many of the activities of the former American Coordinating Committee on Corrosion and the N.A.C.E. Committee on Relations with Other Technical Societies, both of which it replaces.

The Committee is made up of representatives of technical societies and government agencies working actively in corrosion. H. H. Uhlig and K. G Compton represent The Electrochemical Society. Dr. Uhlig was named Temporary Chairman, to hold office until permanent officers are elected at a meeting of the Committee to be held in April during the 1949 N.A.C.E. Conference in Cincinnati. Sam Tour was named Temporary Vice-Chairman. and A. B. Campbell, Executive-Secretary of N.A.C.E., is Secretary ex-officio of the Committee.

Among the activities and objectives suggested for the I.S.C.C. were the following: to prepare and publish periodically a directory of corrosion workers in the United States; to stimulate the publication of reliable corrosion data and to provide publicity for conferences in this field; to provide liaison and promote cooperation among corrosion committees of the member organizations; to continue the work of the former A.C.C.C. subcommittee on standard terms and symbols and extend and revise the "Glossary of Terms Used in Corrosion" published in The Electrochemical Society "Corrosion Handbook"; and to encourage and advise on college courses on the principles and practices of corrosion engineering.

The twenty-one organizations represented on the Committee as of January 7, 1949, are listed below:

Alloy Casting Institute
American Gas Association
American Society of Mechanical Engineers
Electrochemical Society
National Bureau of Standards
National District Heating Association
National Research Council
American Society for Testing Materials
American Institute of Electrical Engineers
Technical Association of the Pulp & Paper Industry
American Chemical Society
American Electroplaters' Society
American Association for the Advancement of Science
Association of American Railroads
American Society of Heating and Ventilating Engineers
American Society for Metals
American Water Works Association
American Foundrymen's Association
American Institute of Chemical Engineers
Federation of Paint & Varnish Production Clubs
National Association of Corrosion Engineers

Gordon Research Conference on Corrosion—1949

The Gordon Research Conference for 1949, sponsored by the American Association for the Advancement of Science, will be held from June 20th to September 2nd at the Colby Junior College, New London, New Hampshire. The facilities of the college have been made available for the conferences.

Meetings will be held in the mornings and in the evenings, Monday through Friday, with the exception of Friday evening. The afternoons are available for recreation, reading, or participation in discussion groups, as the individual desires. Those listed on the program below will be discussion leaders for the subjects named. They will prepare a summary of the subject, with pertinent questions, and direct the discussion from the floor.

Program for Conference

H. R. Copson, *Chairman*

W. S. Loose, *Vice-Chairman*

July 25

H. H. Uhlig—"Theoretical Considerations Pertinent to Localized Corrosion."

Norman Hackerman—"Effect of Condition of the Metal Surface on Localized Corrosion"

July 26

F. L. La Que—"Pitting in Sea Water and Brines"

W. Lynes—"Impingement Attack"

July 27

E. P. Partridge—"Pitting in Boiler Waters and Fresh Waters"

A. Wachter—"Effects of Inhibitors on Localized Corrosion"

July 28

A. Brenner—"Pitting Through Coatings"

R. B. Mears—"Granular, Transgranular, and Intergranular Corrosion"

July 29

F. W. Fink—"Techniques for Studying Localized Corrosion"

Requests for additional information should be addressed to W. George Parks, Director, Department of Chemistry, Rhode Island State College, Kingston, Rhode Island.

Section News

Cleveland Section

Approximately forty members and guests of the Cleveland Section heard an after-dinner talk by Mr. James A. Lee, Society President, on "Society Affairs" at the meeting on January 11th at the Cleveland Engineering Society.

Following Mr. Lee's talk, Dr. George H. Young of the Mellon Institute of Industrial Research gave an excellent presentation of the special problems and mechanisms involved in the protection and control of fouling of ships' bottoms by living marine organisms. This is an old old problem and, as yet, has not been completely solved. Considerable forward strides have been made under the pressure of necessity to operate cargo and fighting ships in distant waters under wartime conditions where frequent docking for bottom cleaning was not tactically practicable.

As a result of intensive pre-war work by both civilian and Naval laboratories on the problem, antifouling paints are now in use by our Navy and are potentially available to the maritime industry generally, having a demonstrated effective life of well over two years. It is now without question that our research produced paints and painting practices far superior to those developed by the Germans and the Japanese.

Discussing the fouling phenomenon, Dr. Young pointed out that when as little as 5 per cent of the underwater surface is fouled—particularly in the region of the stern—the results are a 25 per cent decrease in speed per unit of fuel consumed. The fouled ship is a sluggish ship to handle. When high maneuverability is essential, as in a naval engagement or air attack, a fouled bottom may well mean a lost ship.

The fouling process is complex but, reduced to essentials, the larval forms of the prevalent organisms—free swimming or freely water-borne—are contacting all quiescent underwater surfaces by the thousands during the breeding seasons. Once attached, metamorphosis into a minute adult organism takes place in four to twenty-four hours. The nature of the organism is extremely difficult to discourage and, once attached, the normal movement of the surface through the water will not carry it away. Therefore mitigation involves the prevention of primary attachment and development of the larval forms of marine life.

Dr. Young then presented the theory

of antifouling paints based on the use of toxic surface coverings which have stood the test of time. Basically an antifouling paint kills, stuns, shocks, paralyzes, repels, or otherwise effectively discourages the larval forms of marine plant and animal life that come into immediate proximity to it. Barnacles are not poisoned by eating the paint. This requires the formulations of a paint incorporating a water-soluble toxic in such a manner as to insure a steady supply of dissolved toxic ingredient to the water. While superficially simple, there are requirements to be met: the initial loss of toxic material must not be too high; the painted surface must withstand severe abrasion when the ship is under way; the life should be at least two years; and the cost not more than three dollars a gallon.

Out of scores of toxic agents and hundreds of formulations which have been proposed, only copper and a few of its compounds, along with arsenic and mercury derivatives, have had any substantial usage. Of these the cuprous oxide and copper base paints are most commonly employed in specification paints.

There are three basic types of toxic releasing paints, regardless of the toxic ingredient: (1) gelatinous, water permeated, swollen, semi-hydrophillic vehicles carrying the pigment or pigments; (2) hydrolyzable but with tough hard and strong film characteristics; and (3) non-sacrificing semi- or non-hydrolyzing inert vehicles.

If metallic copper is the sole pigment, the paint film may be quite conductive when immersed. This, of course, produces accelerated electrolytic corrosion on metal hulls after abrasion has occurred. It then becomes necessary to incorporate inert pigment with the copper to break up the gross cathode surface.

It is obvious that careful attention must be paid to the quality and quantity of an undercoat system. For this reason, the use of multiple, carefully designed undercoats are increasingly becoming best ship yard practice.

The meeting was adjourned following the usual discussion period.

Following a dinner on February 8th, the Section had as its speaker Secretary R. M. Burns. After preliminary remarks concerning secretarial and editorial affairs and plans for the coming Philadelphia meeting, the speaker discussed corrosion. He pointed out the importance of corrosion control for the conservation of our mineral resources.

There are two general methods employed in the prevention of corrosion. First, corrosion may be avoided by controlling the nature of the environment in which metallic articles are used. This has only limited application. The principal method of controlling corrosion is to interpose protective film between the metal and environment. Such films may be naturally formed as superficial corrosion products, as in the case of nonferrous metals, stainless steels, etc., or a protective agent such as a dichromate may be introduced into the environment. Fabricated coatings, the organic or paint type, or coatings of non-ferrous metals provide the most important means of corrosion prevention. Lately, cathodic protection has come to be widely applied for the protection of outdoor metallic structures, tanks, and pipe lines.

Dr. Burns discussed in detail the application of the EMF series to corrosion problems. Finally, he illustrated his talk with the usefulness of corrosion cell measurements in the study of special corrosion problems.

CHARLES SANBORN, *Secretary-Treasurer*

Detroit Section

Dr. D. T. Ewing, of Michigan State College, addressed the meeting of the Detroit Section on February 18th at the Sheraton Hotel. Dr. Ewing's subject was "Electrolytic Removal of Trace Elements from Concentrated Solutions."

The speaker included in his discussion the precipitation of cadmium, iron, zinc, chromium, and aluminum by treatment with NaOH and NH_4OH from buffered and unbuffered solutions of nickel sulfate. He pointed out that precipitation of the elements did not occur at a specific pH but rather over a pH range, the amount of the elements being precipitated depending on time and temperature.

Dr. Ewing also discussed the formation of colloidal particles detectable with a nephelometer at a lower pH than that at which precipitation occurred. Further, he discussed the electrolytic removal of copper from nickel solutions pointing out optimum current densities for standard conditions of operation.

A lively discussion period followed.

M. L. BATY, *Secretary-Treasurer*

Midland Section

Over 100 people, including an invited group from the science classes of the

High School, attended the February 8th meeting of the Midland Section at the Dow Auditorium. The featured topic for discussion at this time was "Television"; the guest speaker was Mr. Joseph F. Conway, Jr., of the Magnavox Company, Fort Wayne, Indiana.

The first two events on the program were films: "Crystal Clear" by the Bell Telephone Company on the growth of crystals for frequency modulation, and "Master of Flame" portraying the use of the solid fire extinguishing material of the Ansel Company.

In his speech, Mr. Conway discussed the United States and foreign systems of television operation, relative to regulation and control, by government. He then outlined the allocation system according to population centers, particularly stressing the alternate assignment of channels in close geographical locations to decrease interference. He reported 54 stations in operation in this country at present, the most numerous being in New York, Los Angeles, and Chicago. The year 1949 should see 90 in operation with 310 more applications pending. The present network from the Atlantic Coast to St. Louis, and the future West Coast and Southern networks, with their ultimate cross ties to form a kind of loop as a basis for a country-wide network, were outlined. The coaxial cable necessary for most of this network was described, particularly with reference to all the auxiliary wire circuits for telephone, telegraph, and testing purposes.

Mr. Conway reported that the inauguration of President Truman received coverage by means of television, equal to the total combined attendance of all previous inaugurations. He discussed the other types of popular programs and reported that sponsors are now using this medium of advertising so that the programs are continually improving. Therefore, it is hoped that instead of losing money as the big television broadcasters have done in the past, they will break even and make money, this year and in the future.

The speaker presented figures on production of various manufacturers and the development of the cathode image tube. The various sizes and features of these tubes, particularly the new RCA metal tubes, were very interesting, the speaker reporting that all glass tubes are hand blown involving a bottleneck which the new metal tube may well overcome. He also reported that major moving picture corporations are becoming interested in television broadcasting as such, and are developing 5 station cross-country chains for this purpose. New moving picture corporations are also being formed to produce films for use in television.

A discussion of "Hotel-O-Vision" for use in hotels, hospitals, or apartment houses, involving a set of master receivers and coaxial cables to individual rooms, was particularly interesting. The "Strato-Vision" system proposed by Westinghouse was described as being particularly important for covering rural areas which would be on the fringe of the range of ground stations and possibly subject to interference. The use of "Strato-Vision," involving an airplane, might overcome these difficulties as well as those from echoes and shadows caused by mountains and high buildings. The speaker believed that while two of the probable three frequency ranges are being used for ground installations this third and highest range might be allocated to "Strato-Vision."

Color television was described as being in a very pioneer stage and may be five years or more in the future by FCC regulation. Simultaneous transmission of three primary colors from separate cameras, or transmission of three primary colors alternately are both proposed. Color television has been demstrated on theater size projection.

The speaker pointed out that a television set has from five to seven times the materials, as far as vacuum tubes, condensers, etc., contained in a regular radio set, accounting for differences in price and weight. He discussed tube construction and projection systems as well as various safety features incorporated. He covered the technical aspects of transmission and reception as well as the synchronization of receivers. He then discussed the local picture as far as present and future stations in the vicinity.

Mr. Conway's speech was thoroughly enjoyed by all those who attended the meeting.

F. W. KOERKER, *Secretary-Treasurer*

Niagara Falls Section

The Niagara Falls Section had a very interesting meeting at the Red Coach Inn on January 12th. President of the Society, James A. Lee, addressed the members in an after-dinner talk on "Society Affairs," a discussion of the current activities of the National So-

ciety. A résumé of this talk will appear in a future issue for the benefit of the Society members not attending the meeting.

Following Mr. Lee's talk was an address by Dr. O. M. Morgan of the Allied Chemical & Dye Corporation, Buffalo, New York, on the subject "Use of Detergents in Electrochemistry."

At the previous meeting of the Section, Dr. R. B. Mears, Manager of the Research Laboratory, Carnegie-Illinois Steel Corporation, Pittsburgh, discussed the subject "Causes of Localized Corrosion."

According to Dr. Mears, localized corrosion of metal surfaces is often attributed to the presence of impurities in the corroding metal; however, there are a number of other causes of localized attack which are of far more practical importance than are impurities or constituents. Other known or possible causes are: (1) metallurgical factors, including grain boundaries, orientation of grains, differential grain size, and differential heat treatment; (2) surface roughness, including local scratches and abrasions; (3) differential strain; (4) differential pre-exposure to air or oxygen; (5) differences in degree of aeration, heating, illumination, and agitation; (6) difference in shape and contact with dissimilar metals; (7) certain complex cells may influence the corrosion factor, and externally applied potentials have been found to be responsible for certain severe cases of corrosion.

M. S. KIRCHER, *Secretary-Treasurer*

Pittsburgh Section

Dr. J. M. Bialosky, of the Carnegie-Illinois Steel Research Laboratories, presented a very interesting and complete review of "Laboratory Corrosion Test Methods" in his talk to the Pittsburgh Section, given at the meeting at the Mellon Institute on November 15th.

In general, said Dr. Bialosky, laboratory corrosion tests may be divided into three classifications: quality control tests, evaluation tests to evaluate either materials or environments, and fundamental studies. The objectives, equipment and instrumentation, methods of evaluating corrosion damage, and the significance of specific tests falling under the above classifications were discussed in detail.

At the conclusion of the talk an informal round table discussion of laboratory corrosion testing took place; Dr. Bialosky acted as discussion leader.

The keen interest shown attested to the general success of the meeting.

G. C. ENGLISH, *Secretary-Treasurer*

Notice to Electronics Division

There will be an election of officers for the Electronics Division at the Philadelphia Convention in May. Members are requested to send nominations for officers to Dr. E. F. Lowry, Sylvania Electric Corporation, 126 Washington Street, Salem, Mass., as early as possible before the Convention.

Electrothermic Division Nominees

The nominations listed below for the annual election of officers for the Electrothermic Division will be voted on at the Philadelphia Convention in May.

Chairman: Julian Glasser, Armour Research Foundation, Chicago, Illinois

Vice-Chairman: C. H. Chappell, 3rd, National Carbon Company, Niagara Falls, New York

Secretary: A. E. Pavlish, Battelle Memorial Institute, Columbus, Ohio

Request from the Publication Committee

Many of the manuscripts submitted recently for publication have been duplicated copies which the authors prepared for convenience and easy availability of extra copies. Such copies are perfectly acceptable if their execution is such as to present no problem of clarity. Very frequently, however, we find that some words, letters, figures, or other marks do not reproduce well on copies produced by the hectograph process. A reviewer who is well versed in his subject will find little difficulty with correct interpretation of the missing matter. The editor, however, cannot be expected to correct illegible numbers, literature references, etc. Likewise, the printer is not a technical expert, and is liable to make many mistakes in type setting, especially from copies with poor contrast.

The main difficulty seems to lie with the type of paper chosen for the reproduction from the master sheet. Only certain types of paper lend themselves to a clear transfer of the purple ink. We urgently request authors who want to submit hectographed copies to make sure that the proper kind of paper is used and that all copies which they submit are clearly legible.

Personals

LEON R. WESTBROOK, of C. H. Prutton Associates, was appointed General Chairman of the 1950 Spring Convention of The Electrochemical Society, to be held in Cleveland, Ohio.

MICHAEL A. STREICHER has recently joined the Engineering Research Laboratory, E. I. du Pont de Nemours & Company, Wilmington, Delaware. Dr. Streicher was formerly with the Corrosion Research Laboratory, Bethlehem, Pennsylvania.

M. SIMNAD, recently of Cambridge, England, and the winner of the Weston Fellowship in 1948, is now in the United States where he is continuing his research at the Carnegie Institute of Technology, Pittsburgh, Pennsylvania.

JAN H. REIMERS is now connected with the Falconbridge Nickel Mines Limited, Falconbridge, Ontario, Canada. Mr. Reimers had formerly been with the Aluminum Company of Canada, Arvida, Quebec.

FRANK F. COLCORD, formerly Vice-President and Manager of Metal Sales, of the United States Smelting Refining and Mining Company of New York, is now residing at 2595 Devonport Road, San Marino, California.

C. FRED GURNHAM has been appointed chairman of the Department of Chemical Engineering, in the Tufts School of Engineering, according to a recent announcement of the Trustees of Tufts College. Dr. Gurnham's research papers in the field of chemical and sanitary engineering have appeared in leading technical journals, and he is also chairman of a committee, sponsored by the American Electroplaters' Society, dealing with problems in the field of electroplating.

MORTIMER C. BLOOM, for a number of years a research associate on the M. I. T. staff, and more recently in private practice as a research consultant, has joined the staff of the Naval Research Laboratory, Washington, D. C., as consultant to the Metallurgical Division.

ALBERT O. CROBAUGH is now with the Curtiss-Wright Corporation in Verona, New Jersey. Mr. Crobaugh was previously employed by the Ingersoll-Rand Company, Washington, New Jersey.

Dr. Vinal Honored

Dr. George Vinal, of the National Bureau of Standards, recently was chosen to receive the Department's Meritorius Service Award for outstanding service.

The award was presented by the Secretary of Commerce at a ceremony of the First Honor Awards Program of the Department of Commerce, in the Interdepartmental Auditorium, Washington, D. C., on February 14th.

Professor Erich Müller

One of Europe's best known electrochemists, Professor Erich Müller, of Dresden, Germany, died at the age of 78 on November 15, 1948. Professor Müller, who retired in 1935 from his position at the Institut für Elektrochemie und Physikalsche Chemie in Dresden, was succeeded by Professor Friedrich Müller.

Erich Müller was born in Chemnitz and studied chemistry in Strasbourg and Berlin. Following a stay in England, he went to Göttingen in 1899 to work under Walter Nernst. He later held positions at the Technische Hochschule, Braunschweig and the Technische Hochschule, Stuttgart and at the Institut für Elektrochemie und Physikalische Chemie in Dresden. He held the degree of Doctor Honoris Causa from Stuttgart and during his many years of teaching drew students not only from Germany but from all over the world. Among his many publications are his papers on the electrolysis of alkali chlorides and on the theory of chromium plating. His best known books are: "Das Eisen," "Elektrochemischer Praktikum," and "Die Potentiometrische Massanalyse."

Are Your Dues Paid?

All membership dues for 1949 not paid by April 1st are overdue. Kindly send your check as soon as possible in order to retain your membership.

The Electrochemical Society, Inc.
235 West 102nd Street, New York, N. Y.

New Members

At the meeting of the Executive Committee held on February 2, 1949, at the office of The Electrochemical Society, Inc., 235 West 102nd St., New York City, the following were elected to membership:

ERNST G. BAARS, Signal Corps Engineering Laboratories, Fort Monmouth, mailing add.: RFD 1, Box 279, Long Branch, New Jersey (Battery and Theoretical Electrochemistry)

HARRY M. FISHER, Foote Mineral Company, mailing add.: 4041 Ridge Avenue, Philadelphia, Pennsylvania (Electro-organic and Electrodeposition)

PERCY F. GEORGE, The Dow Chemical Company, mailing add.: 810 State Street, Midland, Michigan (Battery and Corrosion)

JOSEPH M. MARGOLIS, General Electric Company, mailing add.: 3628 Blanche Road, Cleveland 18, Ohio (Electronics)

WALLACE M. McNABB, University of Pennsylvania, mailing add.: Harrison Laboratory of Chemistry, 34th and Spruce Streets, Philadelphia 4, Pennsylvania (Theoretical Electrochemistry and Electrodeposition)

KENNETH B. MEYER, National Lead Company, Research Laboratory, mailing add.: Mill River Road, Chappaqua, New York (Battery)

JOHN S. PEAKE, Indiana University, mailing add.: 1018 E. First Street, Bloomington, Indiana (Theoretical Electrochemistry, Corrosion, and Electrothermic)

PHILIP J. PRANG, JR., mailing add.: Arthur H. Thomas Company, W. Washington Square, Philadelphia 41, Pennsylvania (Theoretical Electrochemistry and Electrodeposition)

FREDERIC W. REUTER, JR., mailing add.: Lamp Department of General Electric Company, Nela Park 85, E. Cleveland 12, Ohio (Electronics)

DEXTER A. SEXTON, JR., mailing add.: National Carbon Company, Niagara Falls, New York (Alkali and Chlorine)

JOSEPH F. SPEAR, Leeds and Northrup Company, 4901 Stenton Avenue, Philadelphia 44, Pennsylvania (Electronics and Theoretical Electrochemistry)

JAMES H. THOMPSON, Du Pont Company, mailing add.: 421 Jefferson Avenue, Niagara Falls, New York (Electrothermic, Electrodeposition, and Industrial Electrolytic)

LEO H. VERBEEK, mailing add.: c/o Bibliotheek-Centrale, N. V. Philips' Gloeilampenfabrieken, Eindhoven, Holland (Electrodeposition and Electronics)

RALPH G. VERDIECK, Foote Mineral Company, mailing add.: 226 E. Benedict Avenue, Havertown, Upper Darby, Pennsylvania (Theoretical Electrochemistry, Electrodeposition, and Electronics)

F. J. WOLFE, mailing add.: National Carbon Company, Inc., P. O. Box 6087, Cleveland 1, Ohio (Battery)

Future Meetings of Other Organizations

National Electrical Wholesalers Association, 41st annual convention, Netherland Plaza Hotel, Cincinnati, Ohio, May 1–6.

American Gas Association, production and chemical conference, Hotel New Yorker, New York City, May 23–25.

American Society of Refrigerating Engineers, 36th spring meeting—cruise, St. Lawrence and Saguenay Rivers, starting from Montreal, June 5–9.

American Institute of Electrical Engineers, summer general meeting, New Ocean House, Swampscott, Massachusetts, June 20–24.

American Society of Heating and Ventilating Engineers, semiannual meeting, Minneapolis, Minnesota, June 21–23.

New York State Association of Electrical Contractors and Dealers, Inc., Golden Anniversary Convention, Saranac Inn, New York, July 2–9.

From the Publishers

AN INTRODUCTION TO THE PHYSICS OF METALS AND ALLOYS by Walter Boas. Published by John Wiley & Sons, Inc., New York, 1948. 193 pages, $3.50.

Written mainly for metallurgist and chemists, this book is a thorough study of the physics of metals. The aims of this field of metallurgy are (1) to explain the properties of metals and alloys in terms of the properties of atoms, and (2) to show how to produce a material with a desired set of properties. The main principle of the book is that the properties and the arrangement of the crystals determine the properties of the polycrystalline aggregates.

Letter to the Editor

Dear Sir:

I read with interest the suggestion by Arthur L. Smith in the February issue that the oral presentation precede publication of papers. This idea deserves earnest consideration. It is perhaps time to re-examine a long-established policy of the Society which differs from that of many other scientific societies. The By-Laws require, I believe, that a paper be submitted in full several months before a meeting and that it be approved by the Publication Committee before its presentation. It has been our object to publish, if possible, such papers before presentation. In recent years it has been found necessary to make exceptions in an increasing number of cases, usually because of the rather long time, a minimum of fourteen weeks, which is unfortunately necessary between submission of a manuscript and its final appearance in the JOURNAL.

The requirements of our present procedure too often result in inadequate time for review, revision, and editing. At least half the papers now given are not, published until after presentation and consequently are not available as the basis for discussion at the meetings. Under the system proposed by Mr. Smith, the results of research could reach the Society more promptly. Informal discussion might also be stimulated by the absence of recording equipment with its attendant complications. Important comment on the work after its publication could then take the form of letters to the Editor.

UPTON B. THOMAS
Summit, New Jersey

Employment Situations

Please address replies to box shown, c/o The Electrochemical Society, Inc., 235 W. 102nd St., New York 25, N. Y.

Positions Available

RECENT GRADUATE, trained in the modern advances in physical chemistry and familiar with electrochemical processes; ion exchange resins; absorption phenomena; etc. Large progressive chemical metallurgical corporation of the Middle West. *Reply to Box A-208.*

CHEMICAL ENGINEER for development work in electronics and corrosion fields. Three to five years' industrial experience in electrochemical development or production required. Large chemical industry in the Southwest. *Reply to Box A-209.*

RESEARCH METALLURGIST, Pacific Coast Area, for research on materials and fabrication of chemical process equipment. Prefer Ph.D. in physical metallurgy with several years' experience. *Reply to Box A-210.*

Positions Wanted

ELECTROCHEMICAL ENGINEER, many years' experience in the production of a wide variety of chemical and electrochemical products. Expert in electrolytic alkali and chlorates. Ph.D. of Columbia 1925; of Chinese birth; speaks English fluently. Desires position in electrochemical engineering. *Reply to Box 329.*

Recent Patents

Selected for electrochemists by Fred. W. Dodson, Chairman of the Patent Committee, from the Official Gazette.

January 4, 1949

Miller, N. F., 2,458,286, Phosphorescent Pigment.
Unschuld, H. M., 2,458,321, Flow Tube.

January 11, 1949

Chester, A. E., and Reisinger, F. F., 2,458,504, Reaction Products of Gelatin and Aldonic Acids and Process for Making Same.
Nachtman, J. S., 2,458,525, Method and Apparatus for Brightening Tin Plate.
Schulz, H. B., 2,458,651, Processes for Producing Low Carbon Chromium Steels.
Brenner, A., and Meites, T. S., 2,458,676, Apparatus for Electroplating.
Booe, J. M., 2,458,827, Electrodeposition of Lead-Tin-Antimony Alloys.
Dyer, J. R., Jr., and Rowan, T. J., 2,458,839, Electrodeposition of Indium and Its Alloys.
Ruben, S., 2,458,878, Alkaline Primary Cell.
Creighton, H. J., and Hales, R. A., 2,458,895, Electrolytic Process for Reducing Sugars.
Jacobs, J. H., 2,458,908, Method of Stripping Electrodeposited Manganese.
Sconce, J. S., and Johnson, A. N., 2,459,049, Photochemical Chlorination of Hydrocarbons.

Feature Section

The Profession of Electrochemistry

III. Opportunities in the Electroprocess Industries

*R. M. Burns**

The chemical industry has become the largest segment of American industrial effort. Through the years of business depression and war-time boom, chemistry has shown continuous and spectacular expansion. Its new products have developed new demands since they have provided new satisfactions to the consuming public.

Allied Industries

Basic to the chemical industry and comprising a large part of it are the so-called electroprocess industries—another term for electrochemical industry. Alkali, chlorine, alloy steels, electrolytic copper, zinc, lead, aluminum, magnesium, graphite, and abrasives, to name some of the principal products of these industries, are both the raw materials of other industries and the finished products of commerce. Electroprocesses are used in the fabrication and treatment of these and other materials. Electroplating, electroforming, and electropolishing are familiar and obvious ones. The storage battery industry employs electrolytic processes in the manufacture of battery plates. Many other examples could be cited.

In magnitude the electrochemical industry can be most readily portrayed by the fact that it consumes about 20 per cent of the nation's electric power—an amount that is three times the total power generated in the United States thirty-five years ago. The steadily increasing demand for the products of electrochemistry suggest a continuing expansion of plant facilities and, what is of the utmost importance, electrochemical engineers to operate them.

University Courses Inadequate

The teaching of electrochemistry has not kept pace with the development of the industry. Many university courses cover only the most elementary phases of the subject, with the result that it has become necessary to employ chemical, electrical, and mechanical engineers and to try to teach them the essentials of electrochemistry. These men usually lack the basic understanding of electrochemistry necessary for their professional advancement and for the most effective prosecution of their work. As a consequence the industries which employ them may well fail to benefit from the latest advances in the field.

When university authorities and students more fully understand the opportunities for electrochemists, courses in the subject will be more widely offered. In the meantime, young college graduates who have had the good fortune to receive training in electrochemistry will find exceptionally attractive industrial opportunities.

R. M. Burns

* Director, Chemical Research, Bell Telephone Laboratories, Murray Hill, New Jersey, and Secretary of the Electrochemical Society.

Technical Notes and Reviews

Physical Properties of Iron Deposited from Chloride Baths*

I. Larson,‡ R. W. Moulton,‡ and G. L. Putnam‡

Abstract

Determination was made of the effects of pH, temperature, current density, and ferric iron concentration on the physical properties of iron deposited from a chloride bath corresponding to the composition specified for the U. S. Rubber Company "Ekko" process. Average tensile strengths varied from 37,700 to 68,700 psi, with elongations of 0 to 12.5 per cent. Of the variables investigated, change in pH produced the most pronounced effect on the properties of the iron.

Introduction

Although electroforming as a practical metal-forming method is relatively new (1), the basic process itself is not. Electrotyping (electrodepositing copper on a wax mold), a kind of electroforming, dates back over one hundred years. The first success in electroforming, except for electrotyping, was apparently in the manufacture of boiler tubes. About thirty years ago, iron tubes were electroformed in Grenoble, France (2); Milford, Connecticut (3); and Niagara Falls, New York (4). Due possibly to lack of understanding of the fundamental variables involved, these plants are not in operation today.

World War II hastened the development of electroforming. The services demanded some unusual parts which could be made in no other way. The facilities of conventional forming methods were overtaxed. Costs were only a secondary consideration. As a result of the accelerated development work, techniques were improved and costs reduced so that now electroforming is finding a definite place among the metal forming methods. This paper describes some of the physical properties of electrolytic iron that are of interest in consideration of electroforming processes.

Experimental

Electrolysis.—The ferrous chloride electrolyte, contained in a ten-gallon earthenware crock, was heated with glass-covered electric resistance elements immersed in the electrolyte. Temperatures were maintained within 0.1°C. of the desired value by means of a thermoregulator. Nickel anode and cathode bars were used because of their corrosion resistance and because traces of nickel do not deleteriously affect iron plating baths. The cell was equipped with resin-impregnated transite cover, stirrer and thermometer, and had suspended within it asbestos cloth bags containing activated charcoal. By means of a constant level device, distilled water or other solution was added continuously as evaporation took place. By addition of hydrochloric acid and ferric chloride to the solution used to replace the water evaporated from the cell, it was possible either to vary the pH and ferric iron concentrations or to maintain them at constant values.

Four 20-gauge, cold-rolled, mild steel cathodes, each 12 in. x 0.75 in. x 0.03 in. (30.5 cm. x 1.9 cm. x 0.07 cm.) were suspended between eight 14 gauge, Armco iron anodes of dimensions 14 in. x 0.75 in. x 0.06 in. (35.5 cm. x 1.9 cm. x 0.14 cm.). The anode-cathode separation distance was 3 inches. Two cathodes were hung from each of two cathode bars giving two parallel circuits through which the current density could be varied independently. There were some errors in the current density determinations because of leakage currents between the cathodes and because the edges of the cathodes received more current than the central portion. Our procedure allowed us to make duplicate trials at two different current densities, with the certainty that electrolyte composition and temperature were identical.

* This paper, which was presented before the New York Meeting, October 13 to 16, 1948, is based on thesis submitted by Irving Larson in partial fulfillment of the requirements for the degree of Master of Science in Chemical Engineering.

‡ The University of Washington, Seattle, Washington.

To prevent contamination of the electrolyte while producing a surface from which the electrolytic iron could be stripped, all electrodes were cleaned by making them the cathode in an alkaline bath (Na_2CO_3, 30 g./l.; Na_3PO_4, 15 g./l.; NaOH, 7.5 g./l.). A steel anode was spaced 4 inches from the work, and the operating conditions were a cell voltage of 6 volts, a temperature of 70° C., and an electrolysis time of 30 seconds. The electrodes were then made the cathode for 3 to 5 minutes in an acid pickling bath (H_2SO_4, 47.5 g.; HCl, 10.3 g.; NaCl, 22.5 g./l.) with duriron anodes, a temperature of 70° C., and a cathode current density of 75 amp. per sq. ft. The cleaning procedures are among those listed by Engel (5).

Bath purification.—The bath contained 100 ± 15 g./l. of ferrous iron as the technical chloride, and 100 ± 5 g./l. technical calcium chloride (6). For small variations in concentrations, the properties of electrolytic iron are not a function of calcium chloride or ferrous chloride concentrations (7, 8). Calcium chloride was determined by Scott's procedure (9), in which iron is precipitated with ammonium hydroxide before calcium oxalate precipitation. Ferrous iron was determined by titration with potassium dichromate using diphenylamine as an internal indicator (9). Ferric iron was determined by the ammonium thiocyanate method (9) using a Klett-Summerson colorimeter.

A most critical variable in the electrodeposition of iron is the purity of the bath, as shown by Stoddard (8) and McFadyen (10). Only by cleaning the bath by boiling with electrolytic iron powder and by filtering through activated carbon was it possible to obtain consistent results. After the treatment with powdered iron ferric chloride was added to bring the ferric ion concentration to the desired value. Iron carbides react with acids to give liquid and solid hydrocarbons (11), and presumably a similar reaction takes place at anodes containing iron carbides. Fig. 1 illustrates the effect of cleaning the bath; strip no. 1 was plated before cleaning, and strip no. 2 after cleaning the bath. For this reason, activated carbon was suspended in asbestos cloth bags in our cell so that the electrolyte would be continuously purified during cell operation. The operation of the stirrer facilitated the diffusion of the electrolyte through the activated carbon.

Tests of physical properties.—The current densities recorded were average current densities, no correction being made for the increased current density on the edges of the specimens. The samples plated rather heavily around the edges, and, in order to produce a uniform cross-section for the tensile tests, the edges were cut off with a shear. This treatment was severe enough in practically all cases to lift up one edge of the plate from the base metal, so that the electrolytic deposit, of approximately 0.03 inch (0.076 cm.) thickness, could be stripped and tensile tests made on the plate itself. Tensile tests were

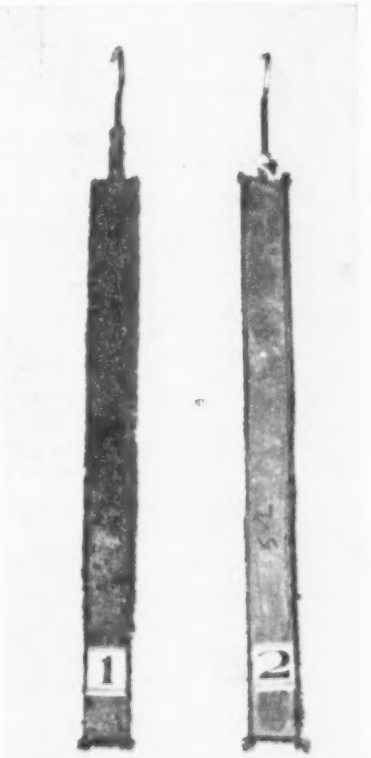


FIG. 1. Iron deposits before purifying electrolyte (no. 1) and after purification (no. 2).

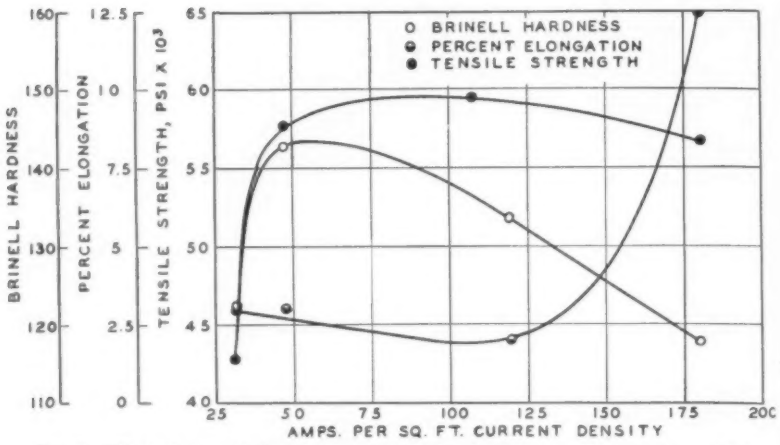


FIG. 2. Effect of current density on properties of iron plate. Temperature, 90° C.; pH, 0.9; ferric iron conc., less than 0.1 g./l.

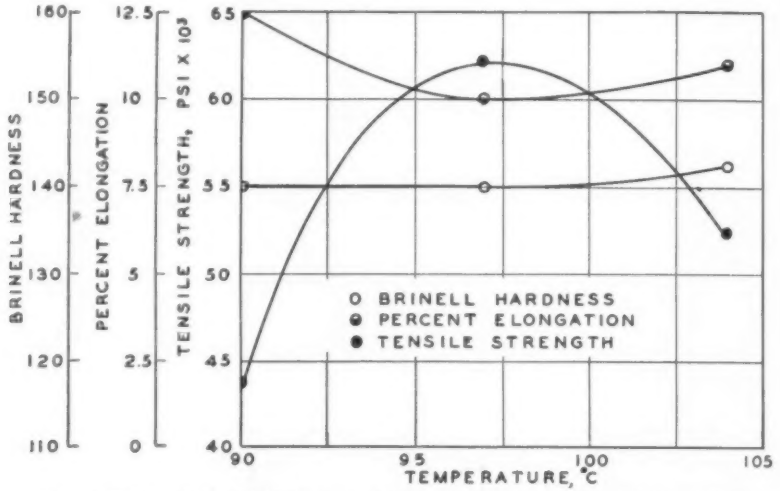


FIG. 3. Effect of deposition temperature on properties of iron plate. Current density, 180 amp./ft.² (19.4 amp./dm.²); pH, 0.9; ferric iron conc., less than 0.1 g./l.

made by standard methods (12), the per cent elongation readings being taken on a basis of a two inch length. Hardness measurements were made with a Barber-Coleman hardness tester. Bar-Col readings were converted to equivalent Brinell hardnesses (13).

Discussion of Results

Current density.—The effect of current density at 90°C. and a pH of 0.9 is shown in Fig. 2. Increasing the current density had little effect on the hardness, caused a slight reduction in tensile

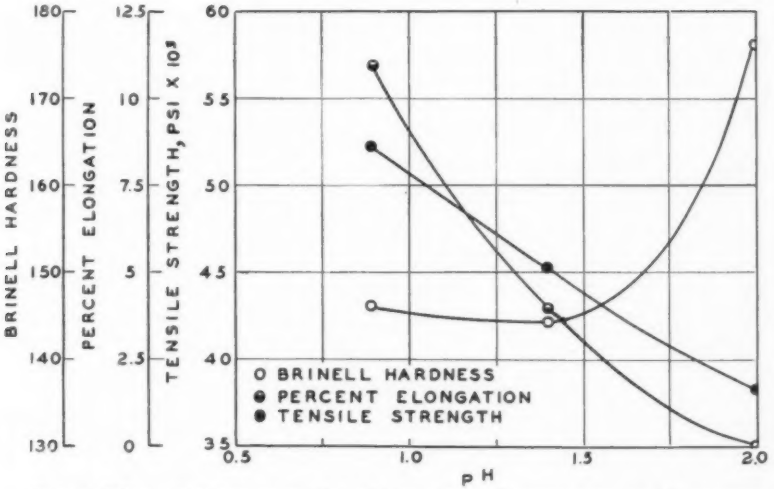


FIG. 4. Effect of pH on properties of iron plate. Temperature, 104°C.; current density, 180 amp./ft.² (19.4 amp./dm.²); ferric iron conc., less than 0.1 g./l.

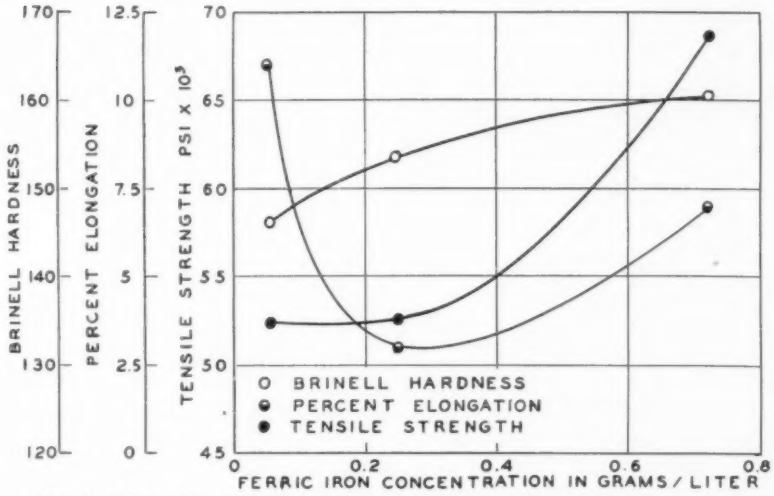


FIG. 5. Effect of ferric iron concentration on properties of iron plate. Current density, 180 amp./ft.²; temperature, 104°C.; pH, 0.6–0.9.

strength, and increased the percentage elongation. The optimum current density at 104°C. was not determined and may be higher than the value at 90°C.

Temperature.—The effect of temperature under our experimental conditions is shown in Fig. 3. The highest tensile strengths were obtained at about 97°C.

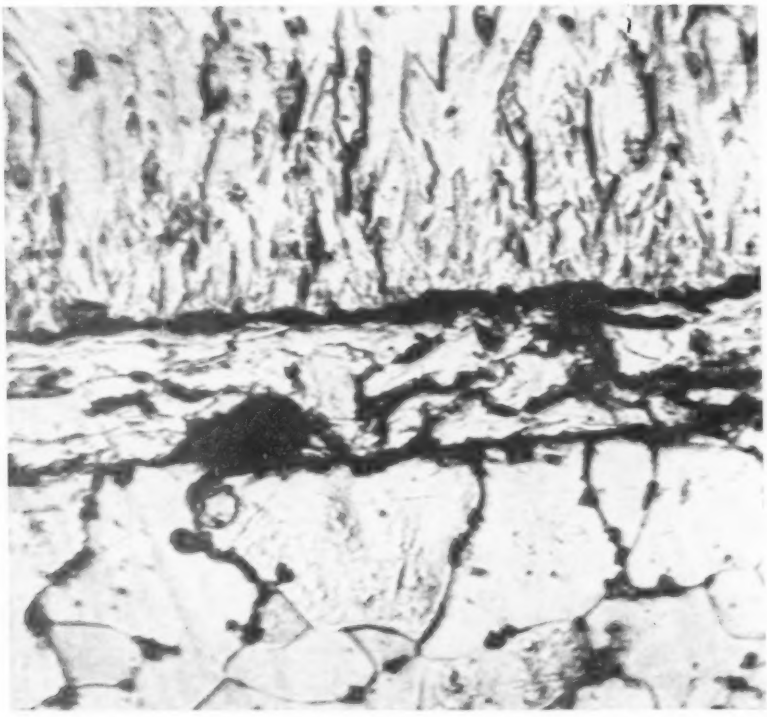


FIG. 6. Iron as deposited. Nital etch. Ferrous iron conc., 100 g./l.; calcium chloride conc., 100 g./l.; pH, 0.9; ferric iron concentration, 0.0565 g./l.; current density, 180 amp./sq. ft.; temperature, 104°C.

pH.—It would appear that pH is probably the most critical variable investigated (Fig. 4). At 104°C., decreasing the pH considerably increased tensile strength as well as per cent elongation, in confirmation of the results of Kasper (7), and of Wallace and Iler. The effect of pH at temperatures above 100°C. is of considerable interest, since iron of excellent physical properties is obtained under very acid conditions.

Ferric ion concentration.—The effect of ferric iron concentration is shown in Fig. 5. Most of the workers in the past have tried to keep the ferric iron concentration as low as possible (8, 10, 14) but the U. S. Rubber Co. (1, 6) reports that moderate ferric iron concentrations are desirable. Increasing the ferric iron concentration from 0.04 to 0.72 g./l. considerably increased the tensile strength.

The data show a better combination of tensile strength and elongation by increasing the ferric iron concentration to at least 0.72 g./l.

Grain structure.—A photomicrograph of one of the specimens is shown in Fig. 6. The large equi-axed crystals are basis metal; the needle-like crystals are electrolytic iron. Interpretation of the nature of the "sandwich" layer cannot be made at this time.

As shown by Storey (15), electrolytic iron was found to pass through a transition from typical needle to conventional ferrite grains at about 910°C.

Conclusions

1. Of the variables investigated, change in pH produces the most pronounced effect on the physical properties of iron deposited from the chloride bath.

2. At the optimum pH of 0.6–0.9, increasing the ferric iron concentration to a value at least as high as 0.72 g./l. gives a better combination of tensile strength and elongation than do lower ferric ion concentrations.

3. The effect of current density on the physical properties of electrodeposited iron was determined at 90°C. The range of current density studied was 25 to 180 amp./ft.^{2} (2.7 to 19.4 amp./dm.^{2}). The effect of temperature was also determined over the range of 90° to 104°C. with a constant electrolyte composition and current density.

Acknowledgments

Sponsorship by the Engineering Experiment Station of the University of Washington made possible this work. The authors wish to express their sincere appreciation to Mr. Ray G. Newbury for constructing the heaters and several other pieces of glass apparatus; to Professor B. D. Mills for his assistance in making the hardness measurements; and to Mr. John Finley for the use of his metallurgical laboratory and for his assistance in taking the photomicrographs.

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Discussion at Portland Meeting

The following discussion of this paper took place at a meeting of the Pacific Northwest Section of the Society, held at the Portland Public Library, Portland, Oregon, September 16th, 1948.

A. B. Scott: Was a photomicrograph of the electrode section made prior to electrolysis to show whether the intermediate film was initially present?

G. L. Putnam: Examination under the microscope showed no intermediate films on the original cathode surfaces.

E. C. Gilbert: What was the current efficiency in this process?

G. L. Putnam: The current efficiency was between 90 and 98 per cent.

Joseph Schulein: Why is it that increasing the pH causes an increase in hardness while increasing current density causes a decrease—considering that increasing it should increase the pH of the electrode film?

G. L. Putnam: I assume that you refer to the general effect of increasing current density on increase in the pH of cathode films. There are two possible explanations, either one of which may apply in the present case:

(a) Current density of itself can have a marked effect, because of changes in crystal size due to variation in the rate of crystal growth and because of changes in the ferrous and ferric iron concentrations in the cathode film. Indeed, with sufficiently high current density the ferrous and ferric iron concentrations would approach zero in the cathode film, as is well known from theoretical studies of the limiting current density.

(b) The hardness of the metal may be increased either by hydrogen in solid solution or by oxides co-deposited with the iron. Decrease in the hydrogen ion concentration should decrease the amount of hydrogen in solid solution if the concentration of ferrous and ferric ions remains constant. On the other hand, oxides tend to be formed in the iron structures as the hydrogen ion concentration decreases. It is evident that change in current density can cause either an increase or a decrease in hardness and tensile strength.

M. Dole: What are the factors influencing the tensile strength? (Factors referring to atomic or molecular structure of iron deposited)

G. L. Putnam: We do not know all of the factors which influence tensile strength, but in general tensile strength

is increased by: (a) elements or compounds in solid solution; (b) decrease in crystal size; (c) strain in the deposited metal. Moreover it is possible that unstable modifications of iron, that is structures other than ferrite, may be deposited under some conditions. Particularly when deposited at low temperatures, electrolytic iron has a higher electrode potential than annealed electrolytic iron.

M. DOLE: How did you measure pH?

G. L. PUTNAM: With a glass electrode, the solution being tested after cooling to room temperature. The absolute values of the pH may be in rather large error because the solutions were cooled and because of errors due to the high salt concentrations. The pH measurements are given because they may be useful for control purposes.

GLENN WARE: I have three questions:

(a) Did you remove the cathode from bath, which may account for the interforced layer?

(b) What was the cleaning process?

(c) What was cathode material?

G. L. PUTNAM: Answering the questions in the order given:

(a) No.

(b) The cleaning process is outlined in the paper, and is a modification of procedure outlined by Engel.

(c) Cold-rolled mild steel cathodes were used.

Discussion at New York Meeting

This discussion of Dr. Putnam's paper took place at the New York Meeting of the Society, October 15th, 1948.

COLIN G. FINK: Part of the early work for this field was carried on at Columbia by Dr. Putnam.

The problem with which we were confronted at that time was what to do with the iron as a waste product. Industrially we have rather large quantities of iron, solutions that we really do not know what to do with. We cannot dig a hole in the ground, and we cannot run them into the ocean and the rivers.

So this opens up one of the easiest means, the best means for the disposal of the waste iron liquors. The solution is very easily made up, and it operates day in and day out. It is one of the best solutions I know of, better than the early ones reported in our own TRANSACTIONS.

I am glad to see this report, and I hope there will be another one shortly on more extensive investigation.

CHARLES L. FAUST: I would like to make another generalizing comment to the effect that information of this type is always of interest to anyone who has to make use of an electrodeposit in what we might call an engineering application.

It is well known that there are stress differences in plated metals associated with the conditions under which they are deposited.

A set of data of this kind would greatly increase in value if stress measurements were included. The emphasis on stress study has been opened again in the Electroplaters' Society. Although the subject of stress has been known for years, recent happenings in the electrodeposited metals have re-opened the interest and greatly enlarged the magnitude or the value of knowing the stress characteristics of the metals.

Not only the nature of the stress but also the magnitude of the stress is interesting.

Reminder to Authors

All papers to be presented at the Fall Convention should be sent, at the earliest possible date, to the Office of the Secretary, 235 West 102nd St., New York N. Y. Manuscripts received before June 15th, If accepted, will receive priority in publication date.

96th Meeting of the Electrochemical Society
LaSalle Hotel, Chicago, Illinois
October 12, 13, 14, and 15, 1949

Editorial

May 1949

Moving the Decimal Point Over

Periodically, there are those of mixed egotism and pessimism who announce that everything of importance has now been done. Some physicists at the turn of this century conveyed the advice that, since all natural phenomena had been discovered, the younger generation would need to content itself with moving over the decimal point through more refined measurements. However, this same younger generation, now grown up, has faced everything, it seems, except the predicted boredom.

There are rumblings of the same kind today—that research has reached its peak. The "cream has been skimmed off" and the younger generation will have to get along, scratching amidst the rubble of a magnificent era just ended—a lachrymose picture that will materialize, if ever it does, for reasons other than lack of opportunities in research.

Perhaps to all young men, at some period of their careers, a particular field of interest seems barren. The world-shaking discoveries of an untrained Michael Faraday, using crude apparatus, appear as belonging to a dim past. The only opportunities remaining are supposedly humdrum routine, and modern success seems more nearly tied in with "get-rich-quick" radio programs than with scientific and engineering discovery.

To yield to this idea is a mistake. Opportunities for creative thought, and rewards that go with such thought are by no means extinct. In electrochemistry, possibilities of new discovery are especially attractive. It was fairly recently that heavy hydrogen or deuterium was found to concentrate in cells used for electrolysis of water. This discovery aided further scientific advance, particularly in the field of nuclear structure, and played a part in developing the atomic pile. The present-day utility of beryllium for alloys and X-ray windows is essentially the triumph of an electrochemical process for recovery of the metal. Recent medical advances concerned with the nature of proteins in blood plasma have been made possible by fundamental electrochemical studies.

As to the future, one good idea making possible the electrochemical recovery of titanium from its ores can cause an impact on the industrial world equal to that of stainless steels or the electrolysis of bauxite. The difficulties to be overcome seem no different from those that confronted Charles Martin Hall in 1886. As a student, Hall heard his professor at Oberlin College describe the marvels of a then new metal called aluminum. This metal, it was said, would be used widely if only there were some reasonable process for its recovery. Armed with this knowledge, a spark of inspiration, and a reservoir of energy and patience, Hall experimented in his father's woodshed and emerged with the essence of the present electrochemical method for aluminum recovery. Hall was richer, and, unlike the situation with radio brands of success, the world also gained. A new structural metal was hereafter available that only a little while before had been a laboratory curiosity. The scene is now set for some electrochemist to repeat history with titanium, the present fair-haired metal of the future.

This is but one of the challenges. Another might be cited with the storage battery. One major advance in this field would be as revolutionary as the discovery of the incandescent lamp. Still other examples are numerous in the fields of biochemistry, electropolishing, and corrosion, not to mention specific examples such as the electrochemical approach to nuclear power, and electricity direct from coal.

Electrochemistry is a subject in which men can do more than move over the decimal point.

H. H. U.

Current Affairs

Varied Programs Featured by Local Sections

Chicago Section

An unusually good program was presented by the Chicago Section at its March 4th meeting. Three speakers were featured, followed by a round table discussion.

Mr. Clifford A. Hampel, Vice-Chairman of the Section, opened the meeting by introducing Dr. C. A. Crowley, moderator of the round table discussion, "What is Electrochemical Research?".

Dr. Crowley, in turn, supplied biographical sketches and introduced the speakers: Dr. J. C. Bailar, Jr., University of Illinois, Dr. L. F. Yntema, Fansteel Metallurgical Corporation, and Mr. J. C. Crummey, Certified Public Accountant. Each speaker briefly gave his views, and then the meeting was opened to questions and opinions from the audience.

The audience participation was free and sincere. The ideas and opinions expressed by both the speakers and those in attendance showed a deep concern for the present condition and future of all phases of research.

Dr. John Bailar, Jr., the first speaker, traced the development of research in universities. The early schools did not engage in it, but in time research developed as an inspiration to professors and students. The published work had great value and influence on society. The university, in developing these abilities, also had to assume responsibility for advancing human knowledge. Some industries realized the value of these activities and shared in the responsibility by contributing unrestricted funds for its support.

When the universities started training research men specifically for industry, sponsored research was instituted. The object of this work varied from pure research to consulting work with graduate students being paid in advanced degrees.

Dr. Bailar then considered the objects and results of research work in line with the objectives of the university. It was his opinion that the research topics should be fundamental and not developmental. Good instruction in research includes a variety of procedures and exercise of the imagination.

Some organic synthesis and mechanisms of reactions were introduced as satisfying the above qualifications while solubilities, corrosion studies, and bright plating were considered unsatisfactory.

The second speaker, Dr. L. F. Yntema, considered electrochemistry as a convenient research tool which has developed and gained a prominent place in industry because of its unique control factors. The advancement of chemistry and electrochemistry has been interlinked with the development through physics and engineering of economical sources of electrical power.

The ability to control energy input is essential in the refining of copper, aluminum, and manganese. Likewise, high energy input has made electric furnaces and their many metallurgical products possible. Electrodeposition and electrophoresis are dependent on the controlled distribution of energy. And, as portable sources of electrical energy, we have primary and secondary cells. These four factors of energy control have made the electrochemical process essential to industry.

Mr. J. C. Crummey reviewed the contributions of science through research to society. His subject, "Electrochemical Research from a Lay Viewpoint," is self-explanatory.

Mr. Crummey emphasized the fact that the great masses of the people really know very little of electrochemistry and what it has done toward the progress of civilization. One reason for this is that many achievements in this field act as stepping stones to a few large dramatic discoveries. Scientists, according to Mr. Crummey, are not good press agents for themselves.

The speaker traced the gradual development of past inventions, through which society has become more complex, more specialized—and this progress has created vast wealth and great responsibilities, the complexities of which can escape the general observer.

Mr. Crummey foresees, however, still greater contributions to industry and employment, but believes these must be achieved through the free enterprise

which has spawned them in the past. He believes that the steady trend to higher skills cannot but uplift mankind, and the new wonders and widely disseminated benefits which may be expected to develop from research in every field of science and industry will increase and sustain a great civilization.

The discussion period following the conclusion of the speeches developed a lively exchange of ideas and information. A comparison of the European and American views in research was discussed. The future of large scale government sponsored research and the development of research personnel were covered at length. The meeting was very successful and enjoyed by all.

H. D. Douglas, Jr., *Secretary*

Cleveland Section

Dr. Herman C. Froelich, of the Lamp Development Laboratories, General Electric Company, Cleveland, addressed the Section on March 8th at the Cleveland Engineering Society.

Dr. Froelich's subject "Lighting by Luminescence—Potentialities and Realities," is one which he is ably qualified to discuss.

Luminescent light, he said, was shown to be characteristically different from incandescent light, so far as its origin and its spectral distribution is concerned. Many technical applications have been found for luminescent light. They are attractive because they offer advantages with regard to the color of light, the efficiency of light sources, and many novelty effects that can be obtained with them.

The most important light sources are those which utilize the luminescence of gases and vapors, and lamps and other devices which utilize the fluorescence of solid phosphors. Some properties of phosphors were discussed and demonstrated.

The speaker concerned himself chiefly with lighting by luminescence specifically with reference to the following three types of possible light sources:

1. Fluorescent and phosphorescent chemicals or paints which require external excitation, chemiluminescent solutions, and bioluminescent sources.
2. Electron lamps which are potentially suitable for high brightness projection type devices.
3. Fluorescent gas discharge lamps of two types: the combination high pressure Hg lamp-phosphors (indirect), and the combination low pressure gas discharge-phosphors (direct) as in the fluorescent lamp.

The possibilities, advantages, and disadvantages of the various combinations were pointed out. The present fluorescent lamp was shown to be the most efficient of all medium wattage light sources and, indeed, very close to the ultimate that is attainable with them.

The talk was concluded with a brief discussion of potential improvement of fluorescent lamps by changing their color through choice of suitable new phosphors.

Charles B. Sanborn,
Secretary-Treasurer

New York Metropolitan Section

The New York Metropolitan Section held a joint meeting with the local section of the National Association of Corrosion Engineers on March 10th at the Building Trades Employers Association, New York City. A well-attended dinner preceded the meeting.

The speaker was Mr. H. A. Humble of the Metals Protection Laboratory of the Dow Chemical Company, Midland, Michigan, and his subject was "Some Observations on the Cathodic Protection of Steel and Galvanized Iron." The Dow Chemical Company has pioneered in the manufacture and use of magnesium for cathodic protection of submerged structures.

In his talk, Mr. Humble pointed out that while reactions at the cathode are paramount, good anodes are required. Anodic behavior is determined by the electrolyte, polarization, protective films, and hydrogen evolution.

In the case of steel piling in sea water, cathodic protection did not help much, because the severest corrosion occurred in the splash zone which could not be reached by the protective current. Painting of this area was recommended. It was interesting that the continuously immersed portion of the piling was anodic to the portion aerated at the tide level.

In the case of galvanized hot water tanks, magnesium anodes always gave good protection at Midland. Furthermore, the tanks acquired a black coating which was itself protective. In aggressive waters at other locations, cathodic protection was more difficult. This seemed related to reversal in the potential between zinc and iron. In

Midland water, zinc was always anodic to iron.

In his summary, Mr. Humble said that the current required for cathodic protection depended on area ratios, potential differences, and the properties of precipitated films. An active discussion followed.

Reported by HARRY R. COPSON

Philadelphia Section

The third meeting of the 1948–49 year of the Philadelphia Section was held on March 2nd in the Harrison Laboratory, University of Pennsylvania. A dinner at the Lenape Club in honor of the speaker, Dr. Charles L. Faust, preceded the meeting.

Chairman R. H. Cherry called the meeting to order and asked for the report of the nominating committee. The following candidates were presented and unanimously elected for the coming year:

Chairman: Arthur Osol, Philadelphia College of Pharmacy & Science
Vice-Chairman: John F. Gall, Pennsylvania Salt Manufacturing Company
Treasurer: George F. Temple, Foote Mineral Company
Secretary: J. F. Hazel, University of Pennsylvania

Following the business meeting, Dr. Faust of Battelle Memorial Institute, and Vice-President of the Society, addressed the Section on the subject "Some Metallurgical Aspects of Electrochemistry."

Many of the phenomena encountered in electrochemistry are associated with surfaces. Electrodeposition of metals, electrolytic oxidation, and electrolytic reduction of organic compounds are examples of reactions which occur at solid-liquid interfaces formed by metals in contact with solutions.

The speaker pointed out that it was possible to classify reactions as occurring either (1), on the liquid side of the interface, or (2), on the solid side of the interface. Great attention has been paid to 1, both experimentally and theoretically. Relatively little attention has been paid to the solid surface of the basis metal or electrode. This is the field of "Surface Metallurgy."

The classical example of the importance of the basis metal is in hydrogen-overvoltage. The solid surface has proved to be a factor in many oxidation-reduction processes not evolving hydrogen (in such cases an equivalent term "metal-overvoltage" may be applied). Processes where the solid surface plays a critical role may be divided into two parts: chemical synthesis and electrodeposition of metals.

Regarding chemical synthesis, the yields and the products themselves, of synthesis reactions, are affected in many cases by the properties of the basis metal. Thus, (a) crystal size, (b) crystal orientation, (c) presence of stresses and strains, and (d) imperfections in the surface layer may have a profound effect.

The same factors affect the properties of electrodeposited metals. The mode of preparation of the surface (polishing, etc.) may distort the crystals of certain metals, causing different results to be obtained in both synthesis and electrodeposition.

About 38 members and guests attended the dinner and about 50 were present at the meeting.

J. F. HAZEL, *Secretary*

Titanium Production Makes New Record

The titanium industry in the United States was featured again in 1948 by record-breaking production, shipments, and consumption of ilmenite, according to the Bureau of Mines, United States Department of the Interior. Shipments of rutile, likewise, were higher in 1948 than ever before. Titanium pigments capacity was expanded again in 1948, close to 10 per cent in that year, and output was at capacity rates for the sixth consecutive year. The output, however, failed again to satisfy all demands and further extensions to plants are in prospect for 1949.

Announcement in 1948 that E. I. du Pont de Nemours & Company would produce titanium metal increased the growing public interest in this commodity, and large-scale production and use of this metal were forecast if metal costs could be reduced substantially. News that the Kennecott Copper Corporation and New Jersey Zinc Company were going to exploit a very large deposit of ilmenite, chief source of titanium dioxide, in Quebec, Canada, stimulated further public interest in titanium.

Ilmenite.—Domestic mines produced and shipped about 372,000 short tons of ilmenite in 1948, compared to 336,533 tons in 1947.

The National Lead Company mine at Tahawas, New York, continued as the

world's leading ilmenite producer and again produced more than ever before. Others were: the Rutile Mining Company of Florida, near Jacksonville; the Riz Mineral Company, Vero Beach, Florida; Yadkin Mica and Ilmenite Company, Finley, North Carolina; Calco Chemical Division, American Cyanamid Company, Piney River, and American Rutile Corporation, Roseland, both in Virginia; and the Ferro-Titan Minerals Company and Live Oak Mines, both in Los Angeles County, California.

Rutile.—Rutile production fell 17 per cent, to 7,100 tons, in 1948, from the peak record for 1947. Shipments, on the other hand, were double the 1947 rate, the lowest since 1943, and established a new high record. Producers in 1948 were the Rutile Mining Company of Florida, Riz Mineral Company, and American Rutile Corporation, already mentioned under ilmenite.

Potential Water Power of the Continents

According to the U. S. Geological Survey (1948), the potential water power of the continents is as follows:

Africa	2.69×10^{12} kw.-hr./year
Asia	1.49×10^{12} kw.-hr./year
Europe	0.672×10^{12} kw.-hr./year
N. America	0.824×10^{12} kw.-hr./year
Oceania	0.197×10^{12} kw.-hr./year
S. America	0.658×10^{12} kw.-hr./year
Total	6.53×10^{12} kw.-hr./year

Our deduction would be that Africa should develop a very extensive electrochemical industry. Raw materials such as copper, cobalt, uranium, gold, etc., are available. The immediate problem is that of cheap transportation.

Future Meetings of The Electrochemical Society

Chicago, October 12–15, 1949
Cleveland, April 19–22, 1950
Buffalo, October 11–14, 1950
St. Louis, Spring, 1951
Detroit, Fall, 1951

Volumes Available

The Society has been notified that Dr. H. H. Willard has a complete set of the TRANSACTIONS for sale. Those who are interested should write to Dr. Willard at the Department of Chemistry, University of Michigan, Ann Arbor, Michigan.

Additional Generators at Grand Coulee Dam

Award of contracts for the last three of 18 generating units which will make Grand Coulee Dam the greatest power producer in the world was announced recently by Secretary of the Interior, J. A. Krug. The installation of these and other generators already on order is being rushed to help alleviate the critical power shortage in the Pacific Northwest.

When the last of these great generators goes on the line in 1952, the plant will have a rated capacity of 1,974,000 kilowatts. With emergency operation in excess of rated capacity, the ultimate continuous production, when water is available, may approximate 2,200,000 kilowatts.

The cost of adding these three units, including necessary switchyard and power plant changes will be approximately sixteen million dollars and will be entirely repaid from commercial power revenues.

Future Meetings of Other Organizations

Radio Parts Manufacturers, annual industry trade show, Stevens Hotel, Chicago, Illinois, May 17–20.

American Gas Association, production and chemical conference, Hotel New Yorker, New York City, May 23–25.

Edison Electric Institute, annual meeting, Traymore Hotel, Atlantic City, New Jersey, May 31–June 2..

American Society of Refrigerating Engineers, 36th spring meeting-cruise, St. Lawrence and Saguenay Rivers, starting from Montreal, June 5–9.

American Society of Heating and Ventilating Engineers, semi-annual meeting, Minneapolis, Minnesota, June 20–22.

American Institute of Electrical Engineers, summer general meeting, New Ocean House, Swampscott, Massachusetts, June 20–24.

American Electroplaters' Society, 36th annual convention, Schroeder Hotel, Milwaukee, Wisconsin, June 27–30.

New York State Association of Electrical Contractors and Dealers, Inc., golden anniversary convention, Saranac Inn, New York, July 2–9.

American Institute of Electrical Engineers, Pacific general meeting, Fairmont Hotel, San Francisco, California, August 23–26.

Personals

C. N. Richardson, for 24 years associated with the Mathieson Chemical Corporation, and previously with the Fixed Nitrogen Research Laboratory, has opened a consulting office at Youngstown, New York, in the Niagara Falls area. Mr. Richardson's specialties include mercury-cathode electrolytic cells, electric furnaces, and high-tension electric discharges.

William Cabler Moore, past president of the Society, retired on March 1st after nearly 29 years of active service as a member of the research staff of U. S. Industrial Alcohol Company. He is now engaged in consulting practice, with his headquarters at Stamford, Connecticut.

Otis W. Fortner is now employed at Air Reduction Sales Company, Murray Hill, New Jersey.

Pekka V. Ekko, one of our Finnish members, writes that he is now teaching in the Technical School of Turku at Suomi, Finland.

E. C. Larsen, who until recently has been employed at the J. T. Baker Chemical Company, is now with Sylvania Electric Products Inc. at Towanda, Pennsylvania.

James C. Gould of the Federal-Mogul Corporation, Detroit, Michigan, has moved to the Federal-Mogul Corporation's Research & Development Division at Ann Arbor, Michigan.

Letters to the Editor

Exemption from Dues?

Dear Sir:

The by-laws of the Society provide that "Members who have reached the age of sixty-five and who have paid dues for thirty years shall thereafter be exempt from the payment of annual dues; they shall receive the Journal of The Electrochemical Society without charge."

It is found that a relatively large number of our members qualify for the application of this rule at the present time. A few of these have requested that it be applied to them, and in such instances the rule is now in force. It has not however been applied to the membership of the Society in general.

The present financial condition of the Society, while sound, does not admit of an extensive application of the rule in question but it is realized that members who have qualified under this by-law are entitled to receive its benefits. On the other hand, it is believed from discussions with such members, that in most cases they would prefer not to avail themselves of the privilege if it presents a financial problem.

It is now proposed to eliminate this provision from the by-laws and the necessary steps for the amendment will probably be taken at an early date. However it is felt that those who are qualified at this time and wish to avail themselves of this privilege should have an opportunity to do so, but that the Secretary's office should be notified by them within a reasonable time—not later than four months from this date—and that without such notification it will be understood that the privilege has lapsed.

I am sure that the Secretary will appreciate a prompt response from those now qualifying who wish to have the present by-law applied in their own cases—as they are fully entitled to do. However, the directors of the Society will be glad to have the privilege waived—in which case no advices to the Secretary will be needed—by as many of the qualifying members as can conveniently sacrifice their own interests to those of the Society as a whole.

The writer is interested in this situation in the dual role of (1) a member who qualifies for the application of the by-law in question and (2) treasurer of the Society for the last several years to whom the financial problem is real and urgent.

William W. Winship
Freeport, L. I., N. Y.

Lists of Periodicals

Dear Sir:

I like very much the format of the Journal. It is really a nice substitute for the Bulletin and the preprints. I would, however, like to suggest in this connection that the "Recent Periodical Literature" which was a regular feature in the Bulletin be continued in the Journal. I feel that this item is a convenient and useful source of reference covering important contributions in electrochemistry and its allied branches.

T. L. Rama Char
Bangalore, India

Book Reviews

SCIENCE AT WAR by J. G. Crowther and R. Whiddington. Published by Philosophical Library, Inc., New York City, 1948. 185 pages, $6.00.

This book is an account of the participation of British scientists in the recent war. It was written for the Scientific Advisory Committee to the British Cabinet, and official sources were available to the authors. This is its first appearance in this country, although Blackett refers to it as having been published by H. M. Stationery Office, London, in 1947. The book is written at a layman's level, but very capably.

The authors have chosen four subjects to present, namely radar, operational research, the atomic bomb, and naval applications other than radar. The book deals exclusively with the work of British scientists, except for the section on the atomic bomb. The book is well illustrated, and identifies ideas and applications with names and dates.

The section on radar, which comprises half of the book, is very well presented. Considerable space is given to the early work in this field, starting with the establishment of the Committee of Research on Air Defence in January, 1935. The touch-and-go character of the early British defences is clearly shown. The impact of such components as the magnetron, klystron, and the TR box is indicated, and the principles of the primary weapon-control and navigational radars are presented.

The atomic bomb section is devoted to a background of the relevant theory, and to the handling of the Tube Alloys project, as the British equivalent of our Manhattan District was called.

The section of naval applications includes the Asdic (British sonar), naval anti-submarine weapons, magnetic and acoustic mines, and under-water explosions research. Much of this material is presented here for the first time. It includes a refreshing antidote to the usual state of knowledge: in describing the sweeping of the Scheldt Estuary, it quotes minesweeper personnel as saying, "if we had known what was there, we should almost have despaired."

The authors emphasize the cooperation between the military and scientific personnel that is necessary in order to obtain the best equipment. Both groups must participate as equals, and all of the facts must be made available to the scientists. The formulation of research and development problems is as important as their solution. Failure to attain this close cooperation was a major weakness of both the German and Japanese war efforts.

Scientific participation at the operational level is also of great value, in the recognition and solution of tactical problems; that is, in the field of operational research. This point is brought out by the successes cited in improving anti-submarine bombing, convoy protection, and in minimizing losses in raids by heavy bombers. Here also the story of the early work is very interesting. The major contributions were made by analytical minds, with an appreciation of the elements of statistics and an impulse to express problems quantitatively, irrespective of previous backgrounds. This section is welcome because the importance of operational research is not generally realized. It made a considerable military contribution and enabled some ideas to be implemented in months instead of years. It is also important because of the applicability of the general methods* to many phases of scientific effort and to problems involving large numbers of people.

The authors have done well in omitting tiresome detail and retaining the fundamentals. To assist the reader in referring back to the large number of problems discussed, an index has been provided.

W. H. MACWILLIAMS, JR.

ELECTRONS, ATOMS, METALS, AND ALLOYS by William Hume-Rothery. Distributed by the Louis Cassier Company, Ltd., London, England, 1948. 371 pp., $7.00.

This volume represents an attempt on the author's part to present the essential ideas and some of the involvements of the electron theory of metals at a level within the grasp of the technical mind not specifically trained in higher mathematics and modern physics—i.e., of the "intelligent layman." In so doing, he states frankly that a reading of the present book will not give "any real understanding of the new theories," and that it has been designed primarily for the man who can read it but intermittently.

For his particular pedagogical pur-

* For those who are interested, an excellent summary is given by P. M. S. Blackett in *Advancement of Science*, V, 17 (1948).

poses, the author has decided to give the subject matter in the form of a dialogue. This results in one of the longest conversations recorded since the time of Plato. However, if the attempt falls somewhat short of complete success, the blame may be divided between the difficult subject matter and the novel presentation. Sir William knows his subject and he knows how to write; he has abundantly demonstrated both of these points before. On this occasion we may disagree with his judgment.

The subject matter includes that of both his recent "Atomic Theory for Students of Metallurgy" and the earlier monograph on "The Structure of Metals and Alloys." The reader, eavesdropping on a series of chatty discussions between O. M. (an older metallurgist) and Y. S. (a young scientist), is led with a minimum of pain through the earlier and later theories of the hydrogen atom to the undulatory nature of electrons, the idea of wave mechanics, and the energy states of the hydrogen atom, and of later members of the periodic system. The behavior of the free and the confined electron leads to the electron in a periodic field and the Brillouin zones, to types of bonding, crystal structure, and to the nature of metals, semi-conductors, and insulators. The valency of metals is discussed, then transition elements and ferromagnetism. In the section on alloys there is talk of primary solid solutions, phase equilibrium, intermediate phases, electron compounds, and superlattices. A brief final section outlines the structure of the nucleus, including fission.

The treatment throughout is essentially non-mathematical and the discussions proceed by easy stages. The intent of the dialogue presentation is stated to be to allow a deliberate raising of questions and discussion of difficulties. This purpose is served and the reader does benefit by the discussion. It remains a question whether he might not have benefited more had it been cast into more conventional narrative form. Too often, the fact of conversation is itself distracting; the reader is unavoidably led to infer the characters of the two protaganists from their words, and to follow their development with unwilling interest.

This reader did not like either of the two men. Y. S. is undoubtedly a brilliant student with a staggering memory (he has a quantity of five-digit numbers at his beck and call); he also appears to be an unmitigated prig. For example, regarding research work on the physics of solids, he says, "That is quite beyond your powers, and, to be honest, I shouldn't advise you to encourage your son to try his hand at it, either. It is a job for a first-class mathematician only." Whatever may be the man's and his son's shortcomings, this is a little brutal, though the intent, under the circumstances, is kind.

O. M. shows a patience and tolerance creditable to Job, and turns the other cheek to a good many backhanded slaps at his lack of adequate background, his son's poor chances in physics, the crude state of metallurgical science, and the antiquity of the metallurigcal education. He apparently forgives the rudeness of many such remarks for the considerable truth they frequently contain. But this attitude is somehow incredible in a purported captain of industry. Even on page 371, he has no comment on the statement "The older (i.e., of O. M.'s age) metallurgists were great men—so were the Elizabethan sailors."

The concluding chapter is principally a plea by Y. S., over O. M.'s feeble and half-hearted interjections, in behalf of fundamental research in solid state physics. Much as the reviewer dislikes Y. S., his enthusiasm in urging his point compels a reluctant admiration. While he would zealously reform overnight the painfully evolved existing methods of industrial research and scientific education, his reasons are sound as his haste is unseemly. What he may overlook, however, is that the changes he proposed are in fact taking place; fundamental research does not particularly need a champion—it has been shown to pay.

O. M. may be no physicist, but neither is he a fool; he knows where the money lies. Otherwise, he would never have been at the meeting that brought these improbable characters together in the first place. I am inclined to think that it is his tolerance that restrains him in the last chapter. He was willing to learn and has been taught, but suspects to himself that it may be some time before the physicists invade the casting shop; in the meantime he will exploit whatever is useful that they have to offer. He remembers that metallurgy, if not an abstract science, is not exactly a black art either. He recognizes an overwhelming indebtedness to Willard Gibbs, whose concepts were at least as lofty as Schroedinger's, and is willing to be equally indebted to Schroedinger to-

morrow. He is willing and anxious to promote the science of metals, but if Y. S. should drop around and ask for a job, he is likely to say, with a cultivated British accent, "I'm very grateful to you and all that, old man, and I'd like to help you out. I'll need a mathematical physicist on my staff very soon now—we're going into the semi-conductor field. But—well, really, you know, I don't think you'd be very happy here. A little hard to get along with, what?"

R. G. TREUTING

From the Publishers

TECHNIQUES OF HISTO- AND CYTOCHEMISTRY by David Glick. Published by Interscience Publishers, Inc., New York, 1949. 555 pages, $8.00.

Micromethods for the investigation of tissues *in vivo* and *in vitro* and the analysis of their constituents have been developed by biologists, chemists, and physicists. The author of this manual describes his own experiences with microscopic, chemical, and physicochemical techniques and gives a critical selection of methods and detailed descriptions of equipment, reagents, execution, evaluation, and limitations.

ORGANIC REAGENTS USED IN GRAVIMETRIC AND VOLUMETRIC ANALYSIS by John F. Flagg. Published by Interscience Publishers, Inc., New York, 1948. 314 pages, $6.00.

The objective of this book is to describe the various organic reagents (precipitants) used in gravimetric and volumetric analysis, and to indicate the type of analytical procedure in which they may be used. The material is presented in two sections: one devoted to theory and the other to applications. Information regarding the accuracy and precision of methods is given wherever available. The bibliography is complete and current.

DISSOCIATION ENERGIES AND SPECTRA OF DIATOMIC MOLECULES by A. G. Gaydon. Published by John Wiley & Sons, Inc., New York, 1948. 239 pages, $5.00.

This is perhaps the only book dealing exclusively with the determination of dissociation energies. Dr. Gaydon has written his book mainly from the spectroscopic standpoint. However, he includes detailed treatments of the determination of dissociation energies by thermal methods, and also by controlled electron impact.

New Members

At the meeting of the Board of Directors held on March 3, 1949, at the office of The Electrochemical Society, Inc., 235 West 102nd Street, New York City, the following were elected to membership:

JOHN O. AICHER, Lamp Works of General Electric Company, Nela Park, E. Cleveland 12, Ohio (Electronics)

ALVA C. BYRNS, The Permanente Metals Corporation, 1924 Broadway, Oakland 12, California (Industrial Electrolytic)

CLETUS M. DOUGHERTY, Electrochemical Laboratory, Building 601, U. S. Naval Base, Philadelphia, Pennsylvania (Corrosion and Electrodeposition)

ROBERT G. HUMPHREY, Western Electric Company, 555 Union Boulevard, Allentown, Pennsylvania (Battery, Corrosion, Electric Insulation, Electrodeposition, Electronics, Electro-Organic, Electrothermic, Industrial Electrolytic, and Theoretical Electrochemistry)

JOHN C. KOSMOS, Underwood Corporation, mailing add.: 72 Vernon Street, Hartford 6, Connecticut (Electrodeposition)

VINCENT F. MCDONOUGH, Chemical Products Works, General Electric Lamp Department, 1099 Ivanhoe Road, Cleveland 10, Ohio (Electronics)

HENRY G. MCLEOD, E. I. Du Pont Company, Niagara Falls, New York (Electrodeposition)

PRAVINCHANDRA M. MAKADIA, Jayant Metal Manufacturing Company, mailing add.: 12/2 Sagar Tarang, Cadell Rd., Bombay 28, India (Electrodeposition)

WILBER L. MEIER, Chatham Electronics Corporation, 475 Washington Street, Newark 2, New Jersey (Electronics)

ALBERT F. MILLER, Underwood Corporation, mailing add.: Albany Turnpike, Canton, Connecticut (Electrothermic)

HENRY C. MILLER, Pennsylvania Salt Manufacturing Company, mailing add.: 709 Wyndmoor Avenue, Philadelphia 18, Pennsylvania (Theoretical Electrochemistry, Alkali and Chlorine, and Electronics)

GERARD P. NELSON, J. T. Baker Chemical Company, 12 S. 12th Street, Philadelphia, Pennsylvania (Theoretical Electrochemistry)

ERNEST S. NOSSEN, mailing add.: 236

Harrison Street, Paterson, New Jersey (Battery)

B. K. R. PRASAD, Electric Grid Offices, Government of Bombay, Foreshore Road, Bombay 1, India (Theoretical Electrochemistry, Battery, and Power)

S. C. RAJAGOPALAN, mailing add.: 601 John Jay Hall, Columbia University, New York 27, New York (Theoretical Electrochemistry, Organic Electrochemistry, Corrosion, Alkali and Chlorine, and Electrodeposition)

HOMER L. ROBSON, Mathieson Chemical Corporation, mailing add: 2 Water Street, Lewiston, New York (Alkali and Chlorine)

KENNETH A. ROE, mailing add.: c/o Burns and Roe, Inc., 233 Broadway, New York 3, New York (Electrodeposition, Electrothermic, and Theoretical Electrochemistry)

DAVID SCHLAIN, U. S. Bureau of Mines, mailing add.: P. O. Box 348, College Park, Maryland (Corrosion)

ANTONIO SCORTECCI, mailing add.: Instituto Siderurgico Finsider, Genova, Cornigliano, Italy (Battery, Corrosion, Electric Insulation, Electrodeposition, Electronics, Electrothermic, Industrial Electrolytic, and Theoretical Electrochemistry)

RUDOLPH L. SPURRIER, San Francisco Naval Shipyard, mailing add.: 1466 Bancroft Way, Berkeley 2, California (Electronics)

Reinstatement

JACOB B. MORRISON, Crucible Steel Company of America, mailing add.: 1701 Second Street, Beaver, Pennsylvania (Corrosion and Electrodeposition)

Recent Patents

Selected for electrochemists by Fred. W. Dodson, Chairman of the Patent Committee, from the Official Gazette

January 11, 1949

Rucker, J. T., 2,459,119, Corrosion Retarder.

Bates, H. T., Fergus, D. J., and Craver, A. F., 2,459,123, Water Heating Device with Corrosion Protective Anode.

Gresham, D. C., and Loening, E. E., 2,459,129, Production of Photographic Stencils.

January 18, 1949

Coates, G. E., 2,459,365, Electrolytic Protective Surface Treatment of Magnesium Base Alloys.

Elmendorf, D. E., 2,459,511, Negative Glow Lamp.

Greig, H. G., 2,459,521, Electrolytic Recording.

Lemmers, E., 2,459,567, Positive Column Lamp.

Farris, C. E., 2,459,633, Fluorescent Lamp

January 25, 1949

Bonner, W. F., 2,459,788, Full-Wave Rectifier in Glass or Other Insulating Containers.

Employment Situations

Please address replies to box shown, c/o The Electrochemical Society, Inc., 235 West 102nd St., New York 25, New York.

Positions Available

CHEMICAL ENGINEER for development work in electronics and corrosion fields. Three to five years' industrial experience in electrochemical development or production required. Large chemical industry in the Southwest. *Reply to Box A-209.*

RESEARCH METALLURGIST, Pacific Coast Area, for research on materials and fabrication of chemical process equipment. Prefer Ph.D. in physical metallurgy with several years' experience. *Reply to Box A-210.*

METALLURGIST, for research on various phases of the electrolytic reduction of aluminum. Prefer advanced degree in physical chemistry or electrochemistry and/or five years' industrial experience. Location Washington. *Reply to Box A-211.*

Positions Wanted

ELECTROCHEMICAL ENGINEER, many years' experience in the production of a wide variety of chemical and electrochemical products. Expert in electrolytic alkali and chlorates. Ph.D. of Columbia 1925; of Chinese birth; speaks English fluently. Desires position in electrochemical engineering. *Reply to Box 329.*

RECENT PH D. in Chemical Engineering, Johns Hopkins University, desires position specializing in research or development work. Two years' chemical engineering experience with Chemical Warfare Service prior to receiving doctorate degree. *Reply to Box 330.*

Feature Section

A Report from Your President*

James A. Lee

In an effort to create closer ties between the national organization and the local sections of the Society, I have visited several of the groups this past winter and have tried to inform them regarding recent actions of the parent organization. Perhaps other members of the Society may be reached through this means. I have done so as the need for closer relationships has been very obvious.

First of all I want to report that there is much evidence of growing interest in the Society. While for many years about 36 technical papers were submitted for presentation at a national meeting, the number has been increasing recently. Already more than 80 papers have been received for the May meeting at Philadelphia.

Part of this growing interest is probably due to the new divisions, Electronics and Battery. These divisions show every evidence of becoming among the most popular in the Society.

You will be interested in the fact that the Board has had a request from several of our members in India for permission to organize a local section in their country. There are also prospects of one or two new sections in the United States.

The JOURNAL OF THE ELECTROCHEMICAL SOCIETY completed its first year with the December issue. It appears to have been a success from every viewpoint. Such criticisms as have come to our attention have been of a minor nature. During the first few months it was extremely difficult to obtain manuscripts in time for publication. This difficulty has now been more or less overcome and the flow of manuscripts is satisfactory.

The year's experience has been invaluable. We now believe the time has come to make some changes in the editorial organization. On the recommendation of Secretary Burns the Executive Committee of the Board at a recent meeting appointed Dr. H. H. Uhlig, editor, Dr. H. B. Linford and Mr. U. B. Thomas, associate editors, and Dr. Burns, consulting editor. Miss Eleanor Reid, in recognition of her increased responsibilities in connection with the preparation of the manuscripts and news material for the printer, was promoted to managing editor.

A conservative policy was followed during the first year of the life of the JOURNAL. Publication costs amounted to nearly 50 per cent of the Society's entire budget; a mistake here might have had serious consequences. I am glad to be able to report that publication costs for 1948 were within the budget.

Consequently, we now believe it possible and advisable to make several changes in typography which will improve the appearance of the JOURNAL. The editors are planning other changes to make for greater and wider interest.

Not only has the JOURNAL met the demands of a large number of the members for earlier publication of manuscripts and on a monthly basis, but it has also reduced publication costs by several thousand dollars over 1947.

As a result of this saving, the Society has not raised the price of membership dues; most other societies have been faced with large deficits or increased dues. Further, this saving has helped to meet the costs of office rent, increased staff salaries, and other expenses.

The Ways and Means Committee was asked to consider the advisability of moving the headquarters office to some other city. After serious consideration it reported that the office should remain in New York. Therefore, the lease on the present office space at Broadway and 102nd Street, which expires July 1st, has been renewed for another two years, but at a 10 per cent increase. One reason for considering a move was the fact that it is now difficult to find enough members of the Board living in New York or nearby to make up the required five for the Executive Committee, which must meet monthly.

The office staff has undergone some changes of personnel during the past year and a half which caused some delay in handling the large volume of work. This situation has likewise been improved to the general satisfaction.

* Synopsis of speech made before several of the local sections of the Society.

The Profession of Electrochemistry

IV. The Electrochemical Engineer

*C. L. Mantell**

The profession of the electrochemical engineer is difficult to define because it is not easily limited. A few years ago the Society had a committee on Electrochemical Education of which the writer was chairman. After much discussion of both committee and open round-table type, it was felt that electrochemical engineering should be taught as a section of chemical engineering, with the emphasis on the technical engineering and industrial phases. It was felt that electrochemistry was not a subdivision of physical chemistry. Conductance methods, pH measurements, overvoltage determinations are not electrochemical engineering but merely background therefor. As part of the chemical training, there must necessarily be acquaintance with theories of ionization, neutralization, hydrolysis, amphoteric electrolytes, theories of solutions, Debye theory, and Debye-Hückel equations, and related subject matter. Most of these, if not all, pertain to dilute solutions. In industry, for all intents and purposes, the electrochemical engineer never meets a dilute solution. In the electronic industries he works with minute currents, but his background and theory are from his electrochemical engineering studies, as are the huge magnitude of currents he meets in electric furnace work.

Electrochemistry has been classically defined as the science which treats of the chemical changes produced by the electric current and the production of electricity from the energy of chemical reactions. Theoretically the two branches are of equal importance. Industrially, however, the chemical and physical changes produced by the electric current are by far the more important.

A Hybrid Science

Electrochemical engineering is a hybrid science having many ramifications. It may be considered primarily as a branch of chemical engineering upon which certain parts and aspects of electrical engineering and metallurgy have been grafted. Electrochemical engineering concerns itself not only with all the topics generally considered as electrochemical, but also with the furnishing of power to the industries; the utilization of that power; the design, construction, and operation of the equipment, machinery, and plants employed for the electrochemical products; the economic considerations involved in the competition of chemical and electrochemical methods for the same or similar products, as well as the sale, distribution, and consumption of these materials.

C. L. MANTELL

Subdivisions of the Profession

Electrochemical industries may be roughly divided into several classes: (1) those of an electrolytic nature, further subdivided into those of (*a*) the electroseparation type, represented by alkali and chlorine, (*b*) the electrowinning variety, as represented by copper and

*Consulting engineer, New York, N. Y.

zinc in which the metals are the result of leaching of ore, (c) the electrorefining group, of which electrolytic copper and nickel are examples, and (*d*) the electrodeposition type, represented by electroplating and electroforming; (2) the fused electrolyte group, represented by aluminum, magnesium, and the alkali metals as examples; (3) the electrothermal group, examples of which are calcium carbide, cyanamide, graphite, and the synthetic abrasives; (4) the products of the electric furnace, which is the means of reaching elevated temperatures, such as the ferroalloys, electric steel, and special alloys; (5) the group in which there is conversion of chemical to electrical energy, as represented by batteries; (6) a subdivision which, as the result of oxidation or reduction in electrolytic cells, is devoted to the production of inorganic and organic products; and (7) those concerned with the action of the electric current in effecting reactions and conversions in the gaseous phase. Each group has problems and applications of the chemical and electrical engineering unit processes. The breadth of the industries is shown by the list of products of the electric furnace and electrolytic cell in Table I.

Chlorine and Caustic

Figure 1 shows a flow sheet of chlorine and caustic preparation using mercury cells. This flow sheet is simpler than that of diaphragm cells with evaporators and separation of salt from the salt and caustic effluent of the cell. The mercury cell effluent is free of salt, so that salt separation from caustic is not needed. Yet in both cases only the cell room where the electrolysis takes place is electrochemical; the salt dissolving, brine purification, liquor pumping, chlorine handling, and liquefaction are straightforward chemical engineering.

Batteries

Batteries are in essence products of assembly lines; in the dry cell form, the electrochemistry is in their operation, in storage batteries in their "forming," charging, and discharging. Essentially the industry fits the process definition of chemical engineering.

Plating

Plating is not an industry of itself; it is a finish, competitive with others, and occupies only a small proportionate space in a manufacturing plant. The electroplating portion of an electrolytic tin plate line is perhaps only ten per cent of the mechanism. Material handling at 1000 ft. a minute, continuous operation, fusing of the coating, inspection, cutting, and shearing vastly overshadow the small plating section, while the equipment furnishing the huge amperages required occupies more space.

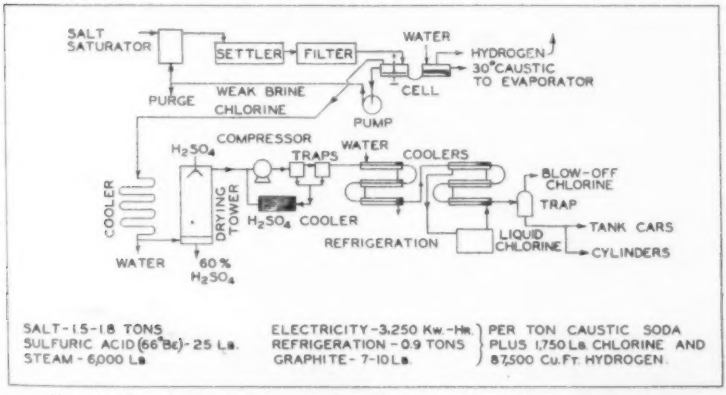

FIG. 1. Flowsheet of the mercury cell process for alkali and chlorine

Table I.—Products of Electric Furnace and Electrolytic Cell

Product	Raw Material	Electric Furnace	Fused Electrolyte	Electrolytic Cell	Application
Alumina, fused	Bauxite (natural aluminum oxide)	x			Abrasives and refractories
Alumina, pure	Bauxite	x			Insulating material, aluminum metal
Aluminum, pure	Aluminum metal		x		Corrosion resistant coatings
Aluminum metal	Bauxite		x		Electric power transmission cable; lightweight alloys for airplanes, automobiles, and trucks; deoxidizing agent for steel; aluminothermic reactions; ammonal (explosives); acid containers; cooking utensils
Ammonium persulfate	Ammonium bisulfate solution			x	Oxidizing and bleaching agent, batteries
Anthraquinone	Oxidation of anthracene			x	Chemicals, dyestuffs
Antimony	Antimony ores			x	Alloying agent
Barium	Fused barium chloride		x		Alloys, electron emission
Beryllium	Beryl		x		Light alloys
Bismuth	Lead refining slimes			x	Alloys
Boron carbide	Anhydrous boric acid and coke	x			Abrasives
Cadmium	Zinc electrowinning slimes			x	Alloys, plating
Calcium	Calcium chloride		x		Special uses, radio tubes, lamps, alloys
Calcium carbide	Lime and coke	x			Acetylene for welding, cutting and lighting, acetone, acetic acid
Calcium cyanamide	Calcium carbide (nitrogen of the air)	x			Fertilizer, ammonia, cyanides
Carbon bisulfide	Coke and sulfur	x			Solvent, insecticide, carbon tetrachloride, artificial silk (viscose)
Caustic	Water, salt			x	Soap, paper industry, explosives
Cerium metals	Rare earth chlorides		x		Pyrophoric alloys, automatic lighters, tracer bullets and shells
Chlorine gas	Water, salt			x	Bleaching, gas warfare, mustard gas, phosgene, chlorpicrin, silicon tetrachloride, explosives, chlorbenzol, water purification, surgery (Dakin solution), detinning, artificial plastics, hydrochloric acid, aluminum chloride for oil refining, sanitation
Chrome yellow	Lead			x	Paint pigment
Chromic acid	Oxidation of chromium sulfate solution			x	Chromium plating, chemicals
Chromium	Complex chromium ores			x	Alloying agents
Chromium	Chromic acid and sulfuric acid solution			x	Plating, alloys
Cobalt	Complex cobalt ores			x	Alloying agent
Copper, pure	Copper ore; crude copper			x	Electrical and brass industries
Cuprous oxide	Copper			x	Paint pigment
Deuterium	Water			x	Chemical for scientific use
Ferrochrome	Chrome ore	x			Special and high-speed steels, armor plate, projectiles
Ferrocolumbium	Residues from tin ores	x			Alloys, addition agents to steel, stainless steels
Ferromanganese	Manganese ore and coke	x			Steel, permanganates
Ferromolybdenum	Molybdenum ore	x			Special steels
Ferrosilicon	Iron, silica rock, coke	x			Making steel, making hydrogen
Ferrosilicon-titanium	Bauxite	x			Steel deoxidizer
Ferrotitanium	Titanium ore	x			Scavenger in steel making
Ferrotungsten	Tungsten ore	x			Special and high-speed steels
Ferrovanadium	Iron vanadate	x			Special steels, automobile steels

Table I—Continued

Product	Raw Material	Electric Furnace	Fused Electrolyte	Electrolytic Cell	Application
Fluorine	Fused potassium acid fluoride; anhydrous HF		x		Chemical
Frary metal	Alkaline earth chlorides		x		Bearing alloys
Gold	Copper refining slimes			x	Jewelry, coinage, industrial alloys
Graphite	Coal and coke	x			Electrodes, lubricants and paints
Hydrogen	Water, NaOH			x	Ballooning, hydrogenated fats
Hydrogen peroxide	Sulfuric acid solution			x	Chemicals, antiseptic, bleaching, oxidizing agent
Hypochlorite	Water, salt			x	Disinfectants, bleaches
Indium	Indium oxide in sulfuric acid solution			x	Nontarnishable silver alloy, jewelry, television
Iodoform	Alcohol, potassium iodide, sodium carbonate solution			x	Antiseptic, disinfectants
Iron, electrolytic	Ferrous ammonium sulfate solution			x	Electromagnetic purposes, powder metallurgy
Iron, pig	Iron ore	x			Steel industry
Iron, pure or "Swedish"	Pyrrhotite			x	Tubes and special steels
Iron powder	Iron ores or ferrous sulfate			x	Powder metallurgy
Lead, refined	Crude lead			x	Alloys, fittings, acid chambers
Lithium metal	Lepidolite, lithium salts		x		Light alloys
Magnesium metal	Magnesium chloride, sea water		x		Flashlight powders, lightweight alloys, tracer bullets and flares
Manganese, electrolytic	Manganese ore			x	Ferrous and nonferrous alloys
Mannitol	Reduction of glucose solution			x	Esters, ethers, chemicals
Mercuric oxide	Mercury			x	Catalyst and chemical
Nickel, refined	Crude nickel			x	Alloys, plating industry, dairy equipment, utensils
Nickel powder	Nickel			x	Powder metallurgy
Nitric acid	Air	x			Explosives, fertilizers
Oxygen	Water, NaOH			x	Oxywelding, oxycutting
Ozone	Air			x	Sterilization of water, sanitation
Palladium	Nickel refining slimes			x	Industrial alloys
Para-aminophenol	Reduction of nitrobenzene			x	Chemicals, photographic developer, dyes
Perborates	Borax			x	Bleaching agents for textiles
Perchloric acid	Hydrochloric acid			x	Salts of perchloric acid
Phosphoric acid	Phosphate rock, coke and sand	x			Acid phosphates, cleaners, food products
Phosphorus	Phosphate rock, coke and sand	x			Matches, phosphorus compounds, phosphor bronze, smoke screens
Platinum	Nickel refining slimes			x	Catalyst, jewelry, industrial alloys
Potassium chlorate	Potassium chloride			x	Primers, matches, dyeing
Potassium hydroxide	Potassium chloride			x	Soap, chemicals, mercerizing cotton, electroplating
Potassium perchlorate	Sodium chlorate solution and converted to potassium salt			x	Oxidizing agent, explosives, medicine
Potassium persulfate	Potassium sulfate solution			x	Oxidizing agent, bleaching
Quartz, fused	Quartz rock	x			Silica tubes, heat-resisting materials, optical uses, lenses
Rhodium	Nickel refining slimes			x	Industrial alloys
Rubber	Latex containing the usual components for compounding rubber			x	Household and industrial rubber goods
Silicon	Sand and coke	x			Silicon steel, hydrogen for balloons, resistance units, silicides, silicon tetrachloride
Silicon carbide	Sand, sawdust, and coke	x			Abrasives and refractories

(*Continued on the following page*)

Table I—Continued

Product	Raw Material	Electric Furnace	Fused Electrolyte	Electrolytic Cell	Application
Silver	Copper refining slimes			x	Jewelry, coinage, industrial alloys
Sodium bichromate	Chromium salts			x	Dyeing, tanning
Sodium chlorate	Sodium chloride solution			x	Weed killer, explosives, matches, oxidizing agent
Sodium metal	Caustic (Castner); salt		x		Peroxides, cyanides, bleaching, mining; alloys, tetraethyl lead, organic synthesis
Sodium perchlorate	Sodium salts, $NaClO_3$			x	Fireworks
Solder	Impure tin-lead alloys			x	Metal joining
Sorbitol	Reduction of glucose solution			x	Humectant, resins and plasticizers, vitamin C, chemicals
Tantalum	Potassium tantalum fluoride			x	Acid-resistant lining for chemical equipment
Thorium	Fused potassium thorium fluoride		x		Electron emission, X-ray targets
Tin, refined	Impure tin, tin dross			x	Tin-plate industry, bronzes
Tungsten	Sodium tungstate solution			x	Alloys, plating, electric bulbs
Uranium	Fused potassium uranous fluoride		x		Alloys
White lead	Lead			x	Paint pigment
Zinc, pure	Zinc ore			x	Brass industry, galvanizing
Zinc powder	Zinc			x	Powder metallurgy

Carbides

While in a carbide plant the furnace might be the electrochemical heart, it has associated with it power supply, transformers, busses, material handling and feeding, electrode mechanisms and controls, gas collection, dust recovery, tapping devices, crushing and grinding machines—the "heart" is the small center of an electrical and chemical engineering plant.

Endothermic Processes

Electrochemical processes of an endothermic nature—i.e., which take place with the absorption of electrical energy—have frequently supplanted purely chemical processes and, in some cases, allowed the production of new products which could hardly be obtained in any other way. Thus copper is now almost entirely refined by electrochemical means. All the chlorine used for chemical manufacture, water purification, sanitation, and bleaching is the product of electrolytic cells, while the manufacture of aluminum, calcium carbide, and the synthetic abrasives of the silicon carbide or fused alumina type could not have reached their present commercial development without electrochemical methods.

In chemical processes, the necessary energy is ordinarily introduced as heat. It often happens that the simplest and most direct of the pure chemical methods for reaching certain ends cannot be used, owing to the great reaction resistances or the impossibility, under a given set of conditions, of converting thermal into chemical energy. As a result, it is often necessary to employ several successive reactions to replace a single direct one. Electrochemical processes usually involve the introduction of the needed energy, not in the thermal manner, but in an electrical one, or the conversion of electric current into thermal energy almost entirely at the desired point. Usually the electrochemical processes are simpler and more direct than their chemical counterparts. Sometimes, however, the electrochemical method is more expensive than its competitive purely chemical one, but is preferably used, inasmuch as the end result is a purer product.

Electrochemical processes, however, cannot stand so much variation in their operation as chemical processes. Generally they operate satisfactorily only under constant conditions. Electrochemical processes must be as simple as possible. Their raw materials should be pure. Elimination of impurities is usually necessary so that side reactions may be prevented and efficiencies of operation

maintained. The electrochemical industries for technical and economic success demand raw materials of high purity, ready availability, and constancy of composition and supply. These are manufactured under constant and reproducible conditions into the desired products.

Power Sources Determine Plant Location

The very nature of the industry, in which power is a basic ingredient, demands low unit price for large homogeneous blocks of power, supplied uninterruptedly. These requirements vary. An aluminum plant must have blocks of at least 20 to 35,000 kw. for each production unit. The power supply must be continuous—it cannot be shut off at will without expensive restarting of operations. Inasmuch as 8 to 10 kw.-hr. are required per pound of aluminum, the cost in mills, not cents, cannot be much more than 2 to 3.5 mills per kilowatt-hour, depending upon location. Even at 2 mills per kilowatt-hour, this power requirement represents between 20 and 25 per cent of the production cost of the metal.

The major existing and potential locations for electroprocess industries in the United States and Canada have been hydro centers. In the East, Niagara Falls and surrounding territory in the United States and Canada has been a traditional center but other demands for the limited power have arisen. The Tennessee Valley has become another important center since the building of the power facilities of the T.V.A. There are other rather isolated centers of major electroprocess industries.

The Northwest

Already in the Pacific Northwest, Bonneville and Grand Coulee Dams, over a high-capacity transmission network covering most of Washington and Oregon, furnish more than half of all the power consumed in the region. However, the development at these two dams is a small portion of 25,000,000 kw. estimated to represent the ultimate potential of the Columbia River and its tributaries in the United States. These are electrochemical centers.

Canada

Canada, particularly the eastern provinces, has some 10,000,000 hp. of its potential 50,000,000 hp. already installed at a number of dams. Most of the development has taken place in the Province of Quebec. Hydro development of the Saguenay has brought Arvida into being as a focal point of electrolytic and electrothermal plants. The Shawinigan Water and Power Company has hydro installations on the St. Maurice River (one of the largest tributaries of the St. Lawrence River) for a total of well over 1,000,000 hp. Shawinigan Falls is an electrochemical industries center.

Growth of Electrochemical Industry

The total power requirements of electroprocess industries in the United States show a tendency to increase at a rate somewhat more rapid than those of industry as a whole. From 1929 through 1943, the total annual power requirements of national manufactures increased about two times—from 71 billion to 147 billion kilowatt-hours. For the same period the total annual requirements of national electroprocess industries increased almost four times—from slightly over 9 billion to almost 38 billion kilowatt-hours.

Electric furnace alloys' power requirements in 1936 were of the order of 1.75 billion kilowatt-hours. By 1943 they had tripled.

In copper and zinc, electrothermal and electrolytic reduction power requirements have continued to climb. At least as far as zinc is concerned, the depletion of ores which may be treated by pyrometallurgical methods makes it imperative that the industry utilize electrowinning procedures to treat the complex lead-zinc ores not amenable to pyrometallurgy. This places a premium on electroprocess methods. The steady upward trend in power consumption in these two industries is marked. From about ½ to 1½ billion kilowatt-hours per year during the period 1926 to 1939, these requirements reached almost 3 billion kilowatt-hours in 1943.

For calcium carbide, chlorine and caustic, electrothermal steel, and other electroprocess industries, there was a steady rise of power consumption prior to World War II, rapid expansion during the war, and continued rise since. These are more or less standard products to which must be added numerous other products of the electric furnace and electrolytic cell, such as metallic calcium, lithium, sodium, phosphorus and electric furnace fertilizer, electrolytic iron, chromium

and manganese, as well as chlorates and perchlorates.

New Fields

The exhaustion of many high-grade raw materials and the need for using what hitherto has been left in the ground or in the tailings pile has focused attention on the utility of the electrolytic cell and the electric furnace in the production of high-grade industrial materials from low-grade and complex ores. Electroprocess industries offer a means for meeting the continually increasing demands of manufacturing industry for high-quality materials of controlled specifications.

A consideration of those industries termed electrochemical shows them to be "process industries" in which power is of more than normal importance. Stepwise they conform to the concept of "unit operations" and "unit processes" of the chemical engineer; they are chemical engineering industries. The different training and functions of the chemist and the chemical engineer are beginning to be appreciated by the layman. The industrial chemist often manages manufacturing plants; the electrochemist with a purely theoretical background and viewpoint never does. The industrial electrochemist or the electrochemical engineer never can get away from the important power and engineering aspects.

Technical Notes and Reviews

A Note on the Possible Role of the Solid Surface in Electroless Plating

*E. E. Glenn, Jr., E. L. Cook, and Norman Hackerman**

Recently, in the course of an experimental investigation, it became necessary to protect the metal surfaces of a pump being used to circulate a corrosive liquid. The surfaces to be protected were of steel, and it was thought that a nickel coat would provide adequate protection. Since there were many recesses in the several pump parts, it was decided to produce the coating by electroless plating (1). This method is distinct from plating due to displacement by the metal on which the nickel is to be deposited, a procedure which was discussed by Piontelli (2) and, more recently, by Wesley and Copson (3).

In electroless nickel plating, the metal deposition is caused by a chemical reducing agent added to the plating bath. The reducing agent used by Brenner and Riddell (1) was sodium hypophosphite, and the process was carried out either in alkaline or acid baths. In an alkaline solution, according to those authors, the hypophosphite oxidized to give hydrogen, which is turn reduced the nickel ion on the surface. In the acid bath, the rate of deposition did not appear to be a function of the hypophosphite concentration, but instead seemed to be controlled by a diffusion process. In either case, however, it was indicated that galvanic effects, presumably due to local cells, were involved. It was reported that the method was satisfactory for the deposition of nickel on steel and on a number of other metals, although in some cases special surface pretreatment was required. For a few metals, lead, cadmium, and zinc, conditions leading to good plating could not be found.

Plating on Non-metallic Surfaces

The plating solution† used in the present work contained 30 grams per liter of $NiCl_2 \cdot 6H_2O$, 10 grams per liter of $NaH_2PO_2 \cdot H_2O$, 10 grams per liter of sodium citrate ($Na_3C_6H_5O_7 \cdot 5\frac{1}{2}H_2O$) for buffering purposes, and distilled water. The pH of the solution was about 6 (the optimum range being from 4 to 6) (1); the temperature of the bath was held between 70° and 90°C. The pump parts were suspended in the bath by means of glass hooks and the bath was stirred occasionally with a glass rod.

In the first experiment, the plating solution was transferred to a clean beaker which had had previous laboratory use. No change was noticeable in the solution

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† Bath No. 3 of reference (1).

while it was being heated to the temperature range indicated above, or while at temperature. On immersing the metal piece, gas bubbles, found to be hydrogen, started coming off of the metal surface. A change in the appearance of the surface was also evident, and it was clear that metal deposition was taking place. After about an hour, a deposit, which was black when viewed from above, began to form on the bottom of the beaker itself. The surface of the deposit toward the glass was smooth, and this was thought to be firm evidence that the material had not fallen off of the part being plated. The solid was identified as nickel and, therefore, the deposit was simply a nickel mirror. Precipitation of nickel elsewhere than on the metal surface was not altogether unexpected since Breteau (4) used such a system to prepare nickel powder in the absence of a metal surface. However, in that case a hypophosphite concentration of the order of 200 grams per liter was required whereas in the solution used in this experiment, the concentration did not exceed 10 grams per liter.

The mirror probably formed on scratches, due to stirring rods, on the floor of the beaker. Therefore, the solution was filtered off into a hitherto unused beaker and the plating resumed without stirring. The nickel did not deposit on the glass in this instance.

A fresh solution was prepared for use in the original container and another plating experiment was started. Deposits again were found with a mirror-like finish next to the glass. The sides of the beaker were also coated and in addition a considerable amount of nickel powder formed throughout the solution. These precipitations might have been caused by seeding the solution in some manner, for example, due to the presence of granules of nickel, scratches, a thin layer of nickel adsorbed onto the walls of the container, or other possible effects due to aging.

To check the possibilities cited, five new Erlenmeyer flasks were used. Fresh solution was placed in three of them, A, B, and C, and solution which had aged for two days at room temperature without evidence of a precipitate was put in the others, D and E. Solution A was seeded with a small piece of the nickel formed in the earlier experiments. Solutions B and D were seeded with nickel prepared by reduction of nickel oxide‡ with hydrogen, and solutions C and E were seeded with a few granules of Raney nickel. Seeding of the last four solutions was carried out in a dry box under an atmosphere of nitrogen. All of the solutions were then heated to 70°–90°C. in air.

Deposition was obtained only in the case of the Raney nickel. The deposit followed the lace-like macrostructure of the seeding material. The bottom of each flask was then deliberately scratched with a glass rod and a nickel mirror formed immediately in all cases. The mirrors followed the scratch marks, the only discernible difference was a somewhat slighter deposit in solutions B and D.

‡ Kindly supplied by Mr. Sidney G. Parker of this department.

Effect of Roughness of Steel Surfaces

In order to determine whether the roughness of a metal surface had an effect, steel coupons were polished to varying degrees of smoothness. The final grits used were in order: coarse sand belt, fine sand belt, and #150, #50, and #0 emery cloths respectively.

All of the coupons were then etched in 10 per cent sulfuric acid, rinsed in distilled water, then in acetone, and finally in benzene. Following this pretreatment, the coupons were placed in a fresh plating bath. After seven hours all of the coupons had picked up about 0.0124 grams per square centimeter of projected area. Variation in weight increase between the several coupons was not detectable, thus indicating that in the range studied the degree of roughness was not critical.

Conclusions

It seems clear that the redox potential of the hypophosphite solution at low pH is such as to permit reduction of Ni^{++} to Ni. Local galvanic effects, such as postulated by Brenner and Riddell (1) may supply energy needed to make the reaction occur in a relatively short time. However, since the nickel did not precipitate or deposit normally on the glass in the hot solution, but did deposit on scratch marks in the glass, it appears that, along with other variables, deposition is dependent on a focus for nucleation.

When one considers the fact that nickel continues to plate once started on a steel surface, but does not deposit from a fresh solution on a seed of nickel formed by the same method, it is reasonable to conclude that the nature of the surface plays

an important role. A detailed explanation for the difference is not yet available, but one possibility is that the metal will not form on an oxided nickel surface. Since hydrogen is produced during the reaction, the solution in the vicinity of the metal surface should be relatively free of dissolved oxygen. However, once the reaction stops, oxygen should again become available to the surface, which in turn then becomes ineffective in initiating deposition.

Tentative support for this hypothesis is gained from the seeding experiments with nickel from reduction of nickel oxide and with Raney nickel. The latter was pyrophoric whereas exposure of the former to air merely caused a moderate rise in temperature. If these characteristics can be related to the amount of hydrogen retained by the respective materials, then an explanation on the basis of the presence or absence of an oxide layer is possible. Transfer of the nickel particles to the solutions took place in an inert atmosphere, but the solutions retained a small amount of dissolved oxygen. In this event, the solution in the immediate vicinity of the Raney nickel particle would still be free of oxygen due to the appreciable amount of hydrogen retained in the catalyst. For this case, precipitation of nickel occurred. On the other hand, the reduced nickel oxide could not maintain an oxygen free atmosphere, surface oxidation took place and, in this case, no metal deposition was apparent.

This leads to a more general conclusion involving adsorption of hydrogen gas at a surface in contact with the solution such that the local gas concentration becomes large enough to reduce nickel ion to the metallic state. The indication is then that the principal requirement is a surface which can adsorb hydrogen to such an extent that the potential of the cell

(anode) Ni ; Ni^{++}/H^{+} ; H_2 (cathode)

is zero or less. Under such conditions nickel deposition should take place.

There are, of course, other explanations possible although not equally valid on the basis of the information at hand. For example, lattice constants for the several crystalline solids involved should be investigated. Further work along these lines is contemplated.

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Plan Now to Attend

The 96th Meeting of The Electrochemical Society

October 12, 13, 14, and 15, 1949

LaSalle Hotel, Chicago, Illinois

Sessions on

Corrosion, Electrodeposition, and Organic Electrochemistry

Facts and Fancies

What is a theory? According to Webster, it may be an analysis of a set of facts in their ideal relations one to another. The word "analysis" in this statement indicates a logical mental process concerning reproducible observations, or facts; hence, the definition comes close to what is termed "theory" in scientific circles. We might, furthermore, consider theory as intermediate between hypothesis, which is an educated guess, and law, meaning the theory is firmly established. Facts alone determine whether an hypothesis emerges eventually as law, or is blocked en route for having run afoul of fact. Many theories expire at birth by the very backslap that sets breathing in motion. Others grow moderately old and venerable, and declare a long list of uncritical admirers and disciples who mistake tenure of theory as proof of its validity. Aristotle's theory of falling weights held sway for many years before the doubting Galileo, using the scientific method, proved it false.

What good is a theory? Interrelating and systematizing facts is a useful function, and this, in effect, constitutes what we call science. Because the systematizing is seldom, if ever, complete or perfect, a theory, furthermore, suggests where new facts are needed, or should be found for the looking. This inspires new experiments which bring out new truths, some expected and more unexpected. Perhaps this is the real justification for the time we spend on theories. As Claude Bernard once expressed it, "Any fact is more beautiful than the most beautiful theory." We might supplement this statement with another—that any scientific theory is useful if it inspires new experiments and discovery of facts.

In all fields of knowledge, the need for holding theory in its proper perspective is an important matter. Outside of science especially, paucity of experimental data or reliable observations gives a false glow of plausibility to many ill-concocted ideas. For this reason, we are periodically besieged with multiple "Aristotle" theories of government, economics, and social relations completely uncontaminated by reality. Instead of facts, we are presented notions based on intuition, inspiration, ignorance, and human perversity. But unless we court disaster, the facts must always take precedence.

Perhaps some comfort can be derived from the knowledge that theories, whether scientific, political, or social, survive in the long run only as they rest on facts. False theories wilt especially rapidly in proportion to the vigor with which men pursue truth. This is a statement of accurate observation as regards the past and of faith as regards the future. Facts are truth, and it is truth—not theory—that sets men free.

Current Affairs

New Officers of The Electrochemical Society

ALFRED L. FERGUSON

J. C. WARNER

E. GIDEON WIDELL

HENRY B. LINFORD

At the annual business meeting of the Society, held in Philadelphia during the 95th Convention, announcement was made of the election of the following officers: Alfred L. Ferguson, President, J. C. Warner, Vice-President, E. Gideon Widell, Treasurer; and Henry B. Linford, Secretary.

A Message From President Ferguson

My Picture of the Recent Past, the Present, and the Future of The Electrochemical Society

To those who requested that I should represent them as President of The Electrochemical Society, I wish to express my sincere appreciation. It gives one much satisfaction to learn that he has so many friends in a great scientific organization, as this Society is, who have enough confidence in him to request that he become their President. To those who expressed a desire that my very good friend, Sherlock Swann, become your President, I state with complete honesty that your choice of Dr. Swann was an excellent one, and I sincerely hope that he will occupy this position at some future time.

Now that the new year is started, I am confident every member of the Society will be guided by the truly democratic attitude and contribute in every way he may to the best interests of the whole.

Past Changes

Usually organizations, as well as individuals, have certain stages when they are afflicted with unusually severe growing pains; stages when changes take place at a greatly accelerated rate. During the past three years, it has been my privilege to observe The Electrochemical Society as it passed through such a stage. It is commonly observed that crises bring forth leaders, and the experiences of the Society during this period justify the observation.

The statement was made many times by various individuals while Dr. Fink was Secretary, especially during the later years, that they were concerned as to what would become of the Society when he turned the work over to another. Dr. Fink did a magnificent job of making all arrangements for meetings. As presiding officer at sessions where papers were being presented he was unsurpassed. He could contribute something of value to every discussion. His great breadth of information, keen sense of humor, truly democratic attitude, and charming personality always contributed life and interest to any occasion. Though the responsibilities for the business affairs of the Society have been necessarily taken over by others, Dr. Fink is frequently called upon for advice concerning important matters. His continued presence at the meetings, together with his charming wife, still contribute greatly, as in the past, to the success of all social functions.

Future Needs Studied

When the time came to make the change, the Society demonstrated its flexibility. Some of the members who had been most active in and most familiar with the affairs of the Society were farsighted enough to realize that considerable changes would become necessary before many years in regard to the general business operations and management and policies of the Society. Their efforts culminated in the appointment in 1944 by President Kirkpatrick of a committee under the Chairmanship of Past President H. S. Lukens. This Committee made an exhaustive study of both the immediate and long range needs of the Society. The final report was made to the Board of Directors in 1946. The nine basic recommendations contained in this report have served as the basis for the procedures which have been incorporated during the last two years, and others that will be made in the near future.

Ways and Means Committee

One of the outstanding results of these recommendations was the organization in 1946 by Past President William C. Moore of the Ways and Means Committee under the leadership of the then Vice-President, James A. Lee. This Committee did an outstanding job during the first year of its existence. During the past year, the Committee has continued its work under Vice-President Ralph M. Hunter. I believe that the Society will continue to find this one of its most active and valuable committees.

Three years ago doubts were expressed, even by some high up in the Society, about the future of the organization. In the brief period of only three years,

the picture has completely changed. Today the Society is on a sounder basis than at any time in its history. This change has been accomplished largely through the remarkable teamwork and devoted efforts of the three men, William C. Moore, George W. Heise, and James A. Lee, who have served as Presidents through these three years. To this group should be added Past President R. M. Burns, who was finally persuaded by the group of Presidents to become Secretary and Editor of the JOURNAL, a key position in the organization during the period of transition. The universally accepted success of the experiments carried out is due primarily to the outstanding ability and past experience of Dr. Burns.

Greater Goals

With the Society running smoothly the future looks bright; but this is no time to relax. The Electrochemical Society has a very long road to travel before it reaches the goal it must strive for.

The United States has, in a comparatively few years, reached the position of leader among the nations of the world in many respects, and one of the most outstanding is scientific achievement. Most of the scientific societies in this country rank at the top throughout the world. I feel that one of the exceptions is our own Society.

This is an undesirable situation, but one which I am convinced may be rectified. At the present time, The Faraday Society has a leading position in the field of electrochemistry. Any person considers it an honor to be accepted as a member, and an even greater honor to be invited to present a paper. There is no sound reason why The Electrochemical Society should not attain such a position.

Our Unlimited Opportunities

This country possesses educational facilities out of all comparison in respect to number of educational institutions, certainly in respect to equipment, and probably also in respect to available personnel. The opportunities for employment of highly trained men in the various divisions of electrochemistry probably surpass the remainder of the world combined. Industry is pleading for electrochemists, salaries in this field are among the highest, and the type of work is rewarding. These unprecedented opportunities present a formidable challenge to The Electrochemical Society to provide recognized leadership in the field. Are we meeting this challenge?

Work Needed at Universities

The facts in the matter are, as much as I dislike to admit it, that the Society does not stand high in the opinion of many administrative officials of educational institutions; only a few offer a course devoted exclusively to electrochemistry. It is a frequent experience to find a student in a chemistry department who has never heard of The Electrochemical Society. Last year at the start of a course in electrochemistry made up of 40 graduate students, most of whom were working for the Ph.D. degree in some field of chemistry, much surprise was expressed that there are openings in industry for specialists in electrochemistry.

It is my opinion that this Society must assume some major new responsibilities if it is to attain the ranking position it should occupy. It has certain duties and obligations which it should logically assume for the good of the great student body, for industry, and for the advancement of science. Industry should likewise assume its share of responsibility.

Cooperation with Industry

It is my hope that some way will be found whereby The Electrochemical Society and industry may cooperate in the promotion of electrochemical training, research and development, and in the wide dissemination of new findings in the field. The publication of a monthly journal was a valuable step, but this is only a meager start toward what must be done.

This responsibility does not rest solely upon the officials of the Society. It is the individual members who must originate and carry out research and write papers of the high caliber necessary for the position to which the Society aspires. Finally, as a major objective in our program, I would suggest that the local sections and various divisions appoint committtees to consider closer contact between the Society and universities, thus emphasizing the importance of adequate training and orientation in the young scientist. Any additional suggestions from members will be welcomed by your President.

LaQue and Mears Receive NACE Awards

F. L. LaQue

R. B. Mears

Mr. F. L. LaQue and Dr. R. B. Mears were recently honored by the National Association of Corrosion Engineers at the annual conference of the Association held in Cincinnati. Dr. Mears received the Whitney Award in recognition of achievement in the field of corrosion science while Mr. LaQue was given the Speller Award for achievement in the field of corrosion engineering.

Both men are well known to corrosion workers, and have for many years been active in the Corrosion Division of The Electrochemical Society and in The National Association of Corrosion Engineers. Dr. Mears was recently elected president of NACE, an office which has been held by Mr. LaQue in the immediate past.

Dr. Mears is manager of the research laboratory at the Carnegie-Illinois Steel Corporation in Pittsburgh, Pa. Mr. LaQue is in charge of the Corrosion Engineering Section, Development and Research Division, International Nickel Company, Inc., New York.

ECS and NACE Sponsor New Publication

"Cathodic Protection, a Symposium" has recently been published by the National Association of Corrosion Engineers. In December; 1947, a Joint Symposium on Cathodic Protection was held in Pittsburgh, Pa., under the sponsorship of NACE and The Electrochemical Society. F. L. LaQue and R. B. Mears were co-chairmen, representing the two societies.

The purpose of the symposium was to offer a review of the state of development of the basic principles of cathodic protection and their application to the control of corrosion. The twenty-three papers presented have been assembled in book form in order to provide for ready reference in a field in which, up to this time, there has been a serious void in the technical literature.

The sponsoring societies feel that this collection of papers will serve a dual purpose. It is sufficiently complete to provide a sound basis for the practical use of the principle of cathodic protection as a means of corrosion prevention. On the other hand, it will serve to indicate the gaps which still exist in our

knowledge of the phenomena and principles involved in the process. It is hoped, therefore, that publication of this group of papers will stimulate further research and thus further extend the scientific foundation upon which improvements in practical application must be based.

The book is being offered for sale to members of The Electrochemical Society and NACE at the special reduced rate of $6.00. The price to the general public is $8.00. It will be sold through the National Association of Corrosion Engineers from its central offices, 905 Southern Standard Building, Houston 2, Texas. The clothbound volume is 203 pages of large format, 8½ x 11 inches, and is profusely illustrated with photographs, diagrams, and curves of technical data.

The usefulness of this collection will be apparent from the broad coverage of the subject indicated in its table of contents, given below:

Electrochemical Principles of Cathodic Protection—R. H. Brown and G. C. English

Characteristics and Field Use of Electrical Instruments for Corrosion Investigations and Cathodic Protection—M. C. Miller

Characteristics of Half-Cells Used as Reference Electrodes—Paul Fugassi

Laboratory Methods for Determining the Current Density Required for Cathodic Protection—R. B. Mears and J. M. Bialosky

Current Required for Cathodic Protection—N. P. Peifer

Detection, Measurement and Mitigation of Stray-Current Electrolysis—Frank B. Fry

Detection and Measurement of Currents Other than Stray Currents—Lyle R. Sheppard

Coordination of Cathodic Protective Installations to Avoid Interference with Adjacent Structures—L. B. Nelson

Use of Rectifiers as an External Source of Protective Currents—F. A. Waelterman

Use of Wind-Driven Generators as an External Source of Protective Currents—M. L. Jacobs

Economic Factors Bearing on Application of Cathodic Protection—D. B. Good

Locations and Materials for Anodes for Impressed Current—Derk Holsteyn

Relative Merits of Various Cathodic Protection Current Sources—G. R. Olson and C. W. Evans

Physical and Chemical Characteristics of Zinc Anodes—E. A. Anderson

Current Output of Light Metal Galvanic Anodes as a Function of Soil Resistivity—E. D. Verink, K. K. Reid, and E. R. Diggins

Fundamental Characteristics of Magnesium Galvanic Anodes—H. A. Robinson

Practical Use of Galvanic Anodes—Hugo W. Walquist and Henry M. Fanett

Behavior of Experimental Zinc-Iron Couples Underground—I. A. Denison and W. Romanoff

Anodic Behavior of Zinc and Aluminum-Zinc Alloys in Sea Water—Thomas P. May, George S. Gordon, and S. Schuldiner

Corrosion and Protection of Underground Power Cables—L. J. Gorman

Effect of Environment Characteristics on Cathodic System Design—F. J. LeFebvre and L. P. Sudrabin

Relations Between Protective Coatings and Cathodic Protection—Guy Corfield

Cathodic Protection in the Control of Stress Corrosion Cracking—Hugh J. McDonald and James T. Waber

Cathodic Protection—A Symposium

The collected papers of the Joint Symposium held in Pittsburgh, December 1947 by NACE and The Electrochemical Society

203 pages—cloth bound—illustrated

Order from: National Association of Corrosion Engineers 905 Southern Standrd Bldg., Houston, Texas. Price: $6.00 to members of ECS or NACE $8.00 to nonmembers

Chicago Plans Early for Large Meeting

The Chicago Section will be host to The Electrochemical Society for the sixth time on the occasion of its 96th meeting on October 12, 13, 14, and 15, 1949. The Society met in Chicago previously in 1910, 1919, 1926, 1933, and 1941.

The plans of the Convention Committee are based on a large attendance such as has marked the meetings held in Chicago in the past. The Committee, which started functioning over a year ago, is under the direction of Clifford A. Hampel, General Chairman, and the following subcommittee chairmen: Jackson Burgess, Finance; R. S. Modjeska, Arrangements; B. F. Freeberg, Registration; J. H. Smith, Entertainment; J. B. Mullen, Plant Trips; L. G. Van de Bogart, Exhibits; and Mrs. C. A. Hampel, Ladies' Program.

Hotel Arrangements

The Convention will be held in the Hotel La Salle, which recently was completely modernized. The Society will have at its disposal for the duration of the Convention the entire 18th floor together with some space on the 17th floor. On the 18th floor are located the Ball Room, a large meeting room, a large foyer, and several lounges. Additional meeting rooms are available on the 17th floor so that several simultaneous sessions may be carried on conveniently in a compact and convenient area. A large refreshment lounge for the exclusive use of the Society also will be located on the 17th floor. A loud speaker will be installed in it so that papers may be announced as these are about to be presented in the meeting room. The La Salle Hotel is located at La Salle and Madison Streets in the Loop. It is conveniently located as to transportation, parking, and shops.

The Indian Summer days make October a favorite time for a visit to Chicago, which has many new attractions, educational and otherwise, for the visitor since the Society's last meeting there in 1941.

Scientific Program

The importance of Chicago as an electroplating center adds much interest and significance to the annual session of the Electrodeposition Division which will be one of the highlights of the meeting. At the Chicago meeting symposium in 1941 there were presented the papers that subsequently constituted the "Modern Electroplating" volume. It, therefore, is fitting that the first revision of this popular book will be coincident with this Chicago meeting. The Committee, in cooperation with the officers of the Division, are planning a program which should attract many of Chicago's practical electroplaters.

CLIFFORD A. HAMPEL

The time of the Corrosion Division's annual session has been changed to the Fall Meeting and, therefore, the Chicago meeting will feature a comprehensive program of papers on this most important subject which plays a big part in the Society's scientific activities.

The annual session on Organic Electrochemistry is scheduled for the Chicago meeting. Dr. C. A. Crowley, Chairman of the Division, promises a full program of papers recording the continued progress in this interesting field of electrochemistry (see page 122*C*).

Ladies' Program

Chicago always has many special attractions for the ladies. Mrs. Hampel and her committee have virtually com-

Michigan Avenue skyline and Grant Park as viewed from the Shedd Aquarium

pleted a most interesting program of entertainment which promises to be outstanding.

Plant Trips

The Committee has practically completed the "plant trip" part of the program to supplement the scientific meetings. There will be an opportunity to see in action industrial plants and the rapidly growing and successful Armour Research Foundation.

A newcomer to the Chicago area is the Technological Institute at Northwestern University, which will interest many of those attending the convention, though a planned trip to it is not scheduled. In addition, the University of Chicago where the first atomic pile was operated, the Museum of Science and Industry, which was visited by the Society as a group in 1941, and many other educational institutions are located within a short distance of the Hotel La Salle.

For relaxation from the more serious part of the Convention program the Entertainment Committee is planning some unusual evening features. For those interested in sports, the Committee is going to see what can be done about those Cubs and White Sox so that the World Series may be played in Chicago!!! However, ticket reservations are not yet being accepted.

Mark Your Calendar Now
for the Chicago Meeting!

Plan to Attend

The 96th Meeting of The Electrochemical Society

October 12, 13, 14, and 15, 1949

La Salle Hotel, Chicago, Illinois

Sessions on

Corrosion, Electrodeposition, and Organic Electrochemistry

Winship Prize Winner

George F. Hausenbauer, Pratt Institute '49, has been chosen Winship Prize Winner for the year 1949.

This award is one year's subscription to the publications of The Electrochemical Society, and it is given annually to the outstanding graduating student of Pratt Institute, Chemical

GEORGE F. HAUSENBAUER

Engineering School. The award is donated by Wm. W. Winship, longtime member of the Society.

George Hausenbauer was born in 1925 and received his secondary education at Bishop Loughlin Memorial High School, Brooklyn. From there he was awarded a Regents Scholarship by the University of the State of New York. In 1944 he entered the U. S. Army and served for 28 months as a medical clerk and identification analyst.

At Pratt Institute Mr. Hausenbauer was a member of the American Institute of Chemical Engineers. His outside interests and hobbies include stamp collecting, handball, chess, and the French language. His interest in electrochemistry stems from a problem in his junior year in which he designed a sodium chlorate plant using the data in Vilbrandt's "Chemical Engineering Plant Design." The winner's occupational interests are production and technical service work. He makes his home at 112-24 197th St., Hollis, Long Island, N. Y.

Faraday Society Holds Discussions

The Faraday Society met for a General Discussion on "Crystal Growth" on April 12th, 13th, and 14th, 1949. The meeting was held in the Department of Physics, The University, Bristol, England.

The Discussion was arranged under four main branches as follows:

(I)—Theory
(II)—Nucleation and Normal Growth
(III)—Modified and Abnormal Growth
(IV)—Mineral Synthesis and Technical Aspects

The meeting was well attended by distinguished scientists from England, the European countries, and overseas.

National Distillers Building New Plant

The National Distillers Chemical Corporation, maintaining executive offices at 120 Broadway, New York City, are building a $10,000,000 plant for the electrolytic production of sodium and chlorine. The company plans a yearly output of 36,000,000 pounds of sodium and 27,000 tons of chlorine. The new plant is expected to be in operation about April 1st, 1950. It will be located at Ashtabula, Ohio.

Electrodeposition Courses at Indian Institute

Regular courses in Electrodeposition of Metals commenced in India at the Central Institute, Koni, Bilaspur, in November 1948. The Central Institute has been started by the Ministry of Labour, Government of India, for the training of instructors, under the principalship of Major D. L. Deshpande who holds several degrees in science and is a member of leading scientific societies.

"Study Abroad"

Fellowship Handbook: an international handbook of study opportunities, called "Study Abroad," has been published by UNESCO. Included in the fellowships, scholarships, and educational exchanges are listed over 10,500 opportunities for international study in 166 subject fields in 27 countries, including the United States. Most of the awards are in science, particularly medicine, public health, engineering, and chemistry.

Electro-Organic Division To Sponsor Excellent Symposium

According to advance notices, the Electro-Organic Division will offer an exceptional program at the Fall Meeting of the Society, to be held in Chicago in October. The symposium is scheduled tentatively for October 14th and 15th, and the preliminary program is as follows:

"Polarographic Behavior of Organic Compounds" by P. J. Elving, Lafayette, Indiana

"Polarographic Investigation of Mercaptobenzthiazoles" by G. Sartori and A. Liberti, Rome, Italy

"Polarographic Studies. I. Aliphatic Polyene Aldehydes. II. Hindered and Unhindered Aromatic Nitro-compounds" by M. Fields, Boston, Massachusetts

"Mechanism of Reduction of Saturated and Unsaturated Ketones" by R. Pasternak, London, England

"Polarography of Azo- and Diazo-systems" by R. M. Elofson, Easton, Pennsylvania

"Polarography of Phthalaldehydic Acid Derivatives" by S. Wawzonek and J. H. Fossum, Iowa City, Iowa

"Complex Species in Organic Polarography" by K. G. Stone, East Lansing, Michigan

"Microelectrode Studies" by A. J. de Bethune, Boston, Massachusetts

"Electrolytic Oxidation of Alcohols" by W. McNevin, Columbus, Ohio

"Electrolytic Reduction of Maleic Acid" by S. Swann, Jr., Urbana, Illinois

"Attempts to Prepare sym-Diphenylethylene Glycol from Mandelic Acid" by G. W. Thiessen, Monmouth, Illinois

"Cathodic Initiation of Vinyl Polymerization" by C. L. Wilson, E. Dineen, and T. C. Schwan, Columbus, Ohio

"Electrohydrogenolysis of Sucrose" by N. F. Murphy, Blacksburg, Virginia

"Performance of Cells in Reduction of Glucose" by M. T. Sanders, Wilmington, Delaware

"Electroreduction of Aromatic Nitrocompounds in Acid and Alkaline Media" by B. B. Dey, Madras, India

Still more papers are being received for this meeting, which promises to be an outstanding one. In addition, a round table discussion is planned for Saturday, October 15th. More detailed plans will be announced in a future issue of the JOURNAL.

Section News

Chicago Section

The Chicago Section had the pleasure of hearing Dr. Herman C. Froelich of the Lamp Development Laboratories, General Electric Company, Cleveland, present a fine lecture on "Luminescence" at the April 1st meeting, held at the Chicago Engineers Club.

The talk covered the history, modern applications, and future aspects of lighting by luminescence materials. In a compact, thorough, and comprehensive discussion, Dr. Froelich covered the field which has been subject to approximately twelve years direct study. Those in other sections who have had the pleasure of hearing this lecture appreciate the interest it aroused and the lengthy question and answer period that followed.

The text of the material is not outlined here as it appeared in the May issue of the JOURNAL under Section News.

The Nominating Committee presented the following nominees for the local section offices for the coming year:

Chairman: Clifford A. Hampel
Vice-Chairman: P. W. Leppla
Treasurer: Simon P. Gary
Secretary: H. D. Douglas, Jr.

H. D. DOUGLAS, JR., *Secretary*

Cleveland Section

The members of the Cleveland Section were guests of the B. F. Goodrich Research Center at Brecksville, Ohio, at their April 12th meeting.

Those present had the enjoyable opportunity of a conducted tour through the recently constructed $6,000,000 research laboratory which is housed in a modern functionally designed building surrounded by extensive acreage.

* * *

Other sections may be interested in a method adopted by the Cleveland Section for the purpose of recruiting new members, both local section associate, and national.

Early in the year the secretary wrote to the members of the section requesting a list of acquaintances potentially interested in The Electrochemical Society. Approximately twenty-four names were suggested. These persons were then notified that for one year they would have the status of associate membership, receiving privileges of such associa-

tion with the section, such as receiving all meeting notices, bulletins, magazines, and other information from the Cleveland Technical Societies.

Toward the end of the program year, those who were classified as potential National members received in one of the membership mailings a membership application blank.

This method appears to be rather effective in introducing new people to our organization. It has already resulted in several new member applications being filed with the National Office.

* * *

At the business meeting the following newly elected officers were named for the Cleveland Section for 1949–50:

Chairman: Ralph A. Schaefer, Cleveland Graphite Bronze Company

Vice-Chairman: Robert C. Heinton, Cleveland Electric Illuminating Company

Secretary: Herman C. Froelich, General Electric Company, Nela Park, Ohio

Treasurer: Charles B. Sanborn, American Steel & Wire Company

CHARLES SANBORN, *Secretary-Treasurer*

Detroit Section

Dr. Paul Winters of General Motors Corporation Research Laboratories addressed the Detroit Section at its March 18th meeting at the Sheraton Hotel.

The subject of Dr. Winters' talk was "Some Applications of Electrochemistry to Chemical Analysis." He covered the electrolytic determination and separation of copper, tin, and lead, indicating typical applications and circuits. The process is used for the determination of lead in gasoline and engine deposits. The speaker also discussed polarography and its use in the analysis of steels and the determination of traces of certain elements in zinc base die castings. Dr. Winters also discussed the theory and applications of electrometric, conductometric, and potentiometric titrations.

Also at this meeting, By-laws were adopted for the Detroit Section.

M. L. BATY, *Secretary-Treasurer*

Midland Section

The Midland Section met at the Dow Auditorium on March 31st, when the members heard the address on "Luminescent Lighting" given by Dr. Herman C. Froelich of the General Electric Company, Cleveland, Ohio.

As at the other section meetings where this talk was given, it was received with the keenest interest and an extensive discussion followed.

The following meeting of the Midland Section, devoted to Ladies' Night, will be reported in the July JOURNAL.

F. W. KOERKER, *Secretary-Treasurer*

San Francisco Section

A dinner meeting of the San Francisco Section was held on March 16th, 1949, at the St. Julien Restaurant, San Francisco.

Members voted acceptance of a constitution based upon the model constitution for local sections submitted at the last meeting of the Local Section Advisory Committee. Nominations were also made for the offices of Chairman, Vice-Chairman, and Secretary-Treasurer for the coming year.

JOHN CALLAHAM

The guest speaker was Mr. John Callaham, Pacific Coast Editor of "Chemical Engineering." His subject was "The Pacific Coast Chemical Industry with Emphasis on the Electrochemical Field."

Mr. Callaham traced the growth of the chemical industry in the Pacific Coast states from the pre-war period to the present time and compared it with the industry on a nationwide scale.

Using population, employment in chemical plants, number of chemical plants, and types of products made as

units for comparative purposes, it was very apparent that the industry on the West Coast is of a different makeup than that of the rest of the country. The average plant is much smaller (about half the size), using employment figures as a guide, the number of plants per capita is greater, and the industry is not as well integrated.

The percentages of national output of various types of chemical products made in the Pacific Coast area are not proportional with the population, nor are they uniformly less. The production of some chemicals is very well represented while the production of others is almost negligible. What is true of the chemical industry as a whole on the West Coast is also true of the electrochemical industry.

Mr. Callaham also quoted some interesting figures on power consumption and power generation in connection with the electrochemical industry. In northern California about 5 per cent of the total power generated is consumed in electrochemical processes. In the Pacific Northwest it is about 25 per cent. The only area where a power shortage exists and will continue to exist for a few years is in the Pacific Northwest. Mr. Callaham's talk was very well received by all who attended.

R. F. BECHTOLD, *Secretary-Treasurer*

Pittsburgh Section

A meeting of the Pittsburgh Section of The Electrochemical Society was held on March 30th, in the Social Room of the Mellon Institute of Industrial Research.

Dr. M. T. Simnad of the Metals Research Laboratories, Carnegie Institute of Technology, was the speaker of the evening and chose as his subject "Recent Corrosion Research at Cambridge." Prior to the meeting, a dinner at the Webster Hall Hotel was held in honor of the speaker.

Dr. Simnad, until recently, was engaged in corrosion research in the Cambridge Laboratories directed by Dr. U. R. Evans. The speaker presented an extremely interesting account of the recent activities of the Cambridge corrosion school. This group has played a very important role in investigating the fundamental mechanisms underlying corrosion phenomena. The methods used to isolate and study films on metals were described and the recent work on the electrochemistry of corrosion was reviewed. Cambridge investigators have explored the shape of the potential fields which surround corroding specimens, with interesting results.

Dr. Evans' recent work on the influence of the size of the corrosion cell upon the mechanism of corrosion, the interpretation of overvoltage, and studies concerning the effect of diffusion and convection at electrodes were discussed. Polarization studies, and investigations of the mechanism of the cathodic reaction in corrosion were also described. The results of recent work on paints which give electrochemical protection were presented and the role of electro endosmosis in corrosion of painted metals was discussed. Investigations of fretting corrosion were mentioned and a description of the recent work on corrosion fatigue at Cambridge was especially interesting.

A lively discussion period followed at the close of this stimulating lecture.

G. C. ENGLISH, *Secretary-Treasurer*

Future Meetings of Other Organizations

American Society of Heating & Ventilating Engineers, semi-annual meeting, Minneapolis, Minnesota, June 20–22.

American Institute of Electrical Engineers, summer general meeting, New Ocean House, Swampscott, Massachusetts, June 20–24.

New York State Association of Electrical Contractors & Dealers, Inc., golden anniversary convention, Saranac Inn, New York, July 2–9.

Illuminating Engineering Society, national technical conference, French Lick, Indiana, September 19–23.

American Standards Association, annual meeting, Waldorf-Astoria Hotel, New York City, October 11–14.

American Gas Association, annual convention, Chicago, Illinois, October 17–20.

American Trade Association Executives, annual meeting, Greenbrier Hotel, White Sulphur Springs, West Virginia, October 24–26.

37th National Safety Congress, Chicago, Illinois, October 24–28

Future Meetings of The Electrochemical Society

Chicago, October 12–15, 1949
Cleveland, April 19–22, 1950
Buffalo, October 11–14, 1950
St. Louis, Spring, 1951
Detroit, Fall, 1951

Personals

DAVID S. NANTZ, who has been in charge of production at the plant of E. I. du Pont de Nemours & Company, Inc., Niagara Falls, New York, has accepted the position of General Manager of National Distillers' new plant for the production of sodium and chlorine at Ashtabula, Ohio.

HARRY K. IHRIG, Vice President and Director of Laboratories of Globe Steel Tubes Company, Milwaukee, Wisconsin, received a citation for distinguished service in engineering from the College of Engineering of the University of Wisconsin at Madison on March 15th.

AHINDRA CHATTERJEE, formerly employed as chemist with Snell & Prideauk, Ltd., Birmingham, England, has joined the Electroplating section of the Central Institute, Bilaspur, India.

W. E. CAMPBELL, of the Bell Telephone Laboratories, Murray Hill, New Jersey, has been awarded the degree of Doctor of Science by his alma mater the University of Witwatersrand, Johannesburg, South Africa. The degree was awarded for Dr. Campbell's fundamental studies on surface reactions of metals, many of which have been published in this JOURNAL.

ROBERT E. PARKINSON, formerly with the Owens-Illinois Glass Company, Toledo, Ohio, is now at the Merchandise Testing and Development Laboratories, Sears Roebuck & Company, Chicago, Illinois.

JAMES P. FUGASSI, Department of Chemistry, at the College of Engineering and Science, Carnegie Institute of Technology, has been promoted to a full professorship, according to a recent announcement.

H. G. ORLIK of RCA Victor Division, Radio Corporation of America, Camden, New Jersey, has been made Standards Engineer in Division Standardizing of that company. In this capacity, Mr. Orlik will be engaged in the development, investigation and standardization of electroplated finishes.

K. L. RAMASWAMY, now Deputy Superintendent of the Government of India Fertilizer Plant, Sindri, India, is making an extended visit to Canada and the United States. At present he is with the Welland Chemical Works, North American Cyanamid Company Ltd., at Niagara Falls, Canada, and later will be in New York City with the Chemical Construction Company. Mr. Ramaswamy was, until recently, with the Mysore Chemicals and Fertilizers, Ltd., in India.

Leppla and Reintjes Receive New Appointments

Great Lakes Carbon Corporation recently announced the appointment of P. W. Leppla as Associate Director of Research and, at the same time, of Harold Reintjes as Associate Director of Development for the Research and Development Division Laboratory at Morton Grove, Illinois.

Book Review

HANDBOOK OF URANIUM MINERALS, Second Edition, by Jack DeMent and H. C. Dake. Published by Mineralogist Publishing Company, Portland, Oregon, 1948. 96 pages, $2.00.

This small book in pamphlet form has been written, as stated in the preface, "primarily for the non-specialist." It is an interesting, popularized account of the occurrence, detection, and mineralogy of the various radioactive minerals in the uranium family. The book contains an acceptable general summary of the world's uranium and thorium deposits and some useful, if elementary, information on tests for uranium and methods of using Geiger counters, electroscopes, etc., for detecting the presence of radioactivity. There is also a fairly complete list of uranium and thorium-bearing minerals. This list, however, contains many species of questionable validity and many that are so rare and complex that little purpose is served in listing them. The section on mineralogy includes all the errors recorded in the literature; for example, the minerals lambertite and uranochalcite are both listed, although these have been discredited for many years.

The book will serve the useful purpose of providing a cursory background for anyone interested in this field as a hobby. It is perhaps wise, however, to insert a word of caution against overenthusiasm on the part of the reader who may feel that the Government's $10,000 bonus is within reach, figuratively in his own back yard, by following the oversimplified directions of this "Guide for the Prospector and Miner."

H. RUSH SPEDDEN

From the Publishers

THE CHEMISTRY AND PHYSICS OF ORGANIC PIGMENTS by Lyde S. Pratt. Published by John Wiley & Sons, Inc., New York, 1947. 359 pages, $6.00.

Included in this book are: theoretical considerations of the relation between color, and chemical and physical structure; the raw materials for synthetic organic pigments; the chemistry involved in the formation of colored products; the typical chemistry of dyestuffs and organic pigments; systematic consideration of structural types; methods of testing known and unknown pigments; analytical procedures and identification; and uses to which the organic pigments are adapted. Special emphasis has been placed on a new interpretation of the significance of physical structure as related to color—a factor of primary importance in the field of pigments.

SCIENTIFIC FOUNDATIONS OF VACUUM TECHNIQUE by Saul Dushman. Published by John Wiley & Sons, Inc., New York, 1949. 882 pages, $15.00.

Flow of gases through tubes and pumps, steam-jet ejectors and mercury-vapor pumps, and the chemical and electrical clean-up of gases at low pressures are discussed in this book. It is a survey of the physical and chemical concepts upon which vacuum technique is based. Mr. Dushman has treated the subject comprehensively, drawing on physics, chemistry, and (to a lesser extent) metallurgy for his facts.

ISOTOPIC CARBON by Melvin Calvin, Charles Heidelberger, James C. Reid, Bert M. Tolbert, and Peter E. Yankwich. Published by John Wiley & Sons, Inc., New York, 1949. 376 pages, $5.50.

The uses of tracers of isotopic carbon, which promise to become increasingly useful in many research laboratories, are described in this book. It lists all published tracer applications up to July of 1948, and includes all syntheses published up to April of 1948. The work is intended to serve as a complete laboratory manual as well as a reference book, and discusses many of the general principles needed for a sound approach to solution of future problems.

INDUSTRIAL HYGIENE AND TOXICOLOGY by Frank A. Patty. Published by Interscience Publishers, Inc., New York. Vol. I, 550 pages, $10.00; Vol. II, 750 pages, $15.00.

This book is an encyclopedic treatment of industrial hazards. Problems covered are: toxic substances and their handling; air contamination, dust and smoke abatement; fire and explosion hazards; radiation hazards; occupational allergies; fatigue in workers; and health control and supervision.

THE STRUCTURE OF MATTER by Francis Owen Rice and Edward Teller. Published by John Wiley & Sons, Inc., New York, 1949. 362 pages, $5.00.

This book summarizes the results of quantum mechanics in such terms as will enable the reader—physicist, physical chemist, or engineer—to use those results much as the chemist has used the concept of the chemical bond. It is intended to serve as an introduction to the study of the theory of quantum mechanics and will aid in interpreting, in physical terms, the abstract implications of the theory.

CRYSTAL STRUCTURE by Ralph W. G. Wyckoff. Published by Interscience Publishers, Inc., New York, 1948. Section 1, 600 pages, $8.00.

A new issue of the classic in its field, this book collects the results of all available determinations of atomic positions in crystals. Since the thousands of crystals must be reviewed and many more are being added each year, the present edition of this collection is presented in loose-leaf form to facilitate keeping it up-to-date. An exhaustive bibliography is included.

AQUAMETRY by John Mitchell, Jr., and Donald Milton Smith. Published by Interscience Publishers, Inc., New York, 1948. 460 pages, $8.00.

Aquametry is a generic name proposed for all analytical procedures used in the measurement of water. The principal objective of this book is to make available to chemists the various analytical uses of the Karl Fischer reagent. A broad review is also given of most of the other techniques for the determination both of water and of the organic functional groups discussed. The book includes the results of several years' experience in the authors' laboratory and contains a great deal of previously unpublished data both on determinations of free water and on quantitative analyses for organic functional groups.

Letters to the Editor

Pseudomorphic Continuation?

Dear Sir:

The article "Surface Preparation by Electropolishing" of Dr. Charles L. Faust that appeared in the March 1949 JOURNAL is interesting and should prove to be very valuable in the understanding of the various benefits obtained by electropolishing, which apparently far transcend the production of surface smoothness.

In the article, Dr. Faust shows in Figure 4, a photomicrograph in which there is apparent reproduction of the crystal size of the base metal stainless steel by the nickel plate deposited thereupon and stated that it was "a pseudomorphic continuation of the true crystals of the stainless steel." I may be confused in my definition of a pseudomorph but I would imply from the statement that if this is a pseudomorphic continuation of structure that the nickel plate actually has assumed the crystal structure of the stainless steel.

I am writing to inquire whether Dr. Faust or any readers of the JOURNAL have any proof to offer that such pseudomorphic continuation does occur beyond the first few layers of atoms deposited. We all grant that such structures are continuation of the actual *crystal size* of the base metal but one would naturally believe that the electrodeposit would assume its normal crystal structure. For example, if continuation of the crystal size is observed when a cubic type metal is deposited on a tetragonal base metal structure, has anyone ever observed a true pseudomorphic tetragonal structure in the cubic metal being electrodeposited? I believe the problem could be solved very simply by X-rays rather than by electron diffraction and perhaps such tests have already been made.

WALTER R. MEYER
New Haven, Connecticut

Dear Sir:

Dr. Meyer has raised an interesting question in his letter to the Editor. Figure 4, to which he refers, involves 18% Cr-8% Ni stainless steel (austenitic). Its lattice parameter is very close to that of nickel, so it would not be difficult for nickel plate to pseudomorphically continue the crystals of the stainless steel. The term "pseudomorphic continuation," as used in the paper, was intended to have the meaning which Dr. Meyer has recognized in the second paragraph of his letter. I am sorry to reply that I have seen no results of X-ray analysis of electrodeposited metals to determine whether the crystals are truly pseudomorphic continuations of those in the basis metal surface. Of course, the lattice parameters of the two metals will have to be nearly the same (probably within 10 to 15%) in order that such crystal continuation can take place.

In situations where true pseudomorphic continuation of the basis metal crystals might be found, it is also probable that after some initial period of electrodeposition, the plate will assume whatever crystal structure is normal for the conditions of electrodeposition. We are planning to secure X-ray data bearing directly on Dr. Meyer's question and will publish the results when they are available.

CHARLES L. FAUST
Columbus, Ohio

"Survival Through Chemistry"

Dear Sir:

Your editorial "Survival Through Chemistry" in the March 1949 issue of the JOURNAL has prompted me to voice my opinion in writing for the first time.

I would like you to quote your definite references from which you obtained your statement that our natural resources are declining steadily. I have not as yet read any such startling statements and surely it is a frightening enough thought to warrant nationwide publicity through our public mediums of radio, newspapers, etc. Perhaps in our atomic age we worry too much about too many things. A century or so ago our grandparents had not the fears of the decreasing natural resources, cancer, the Rh factor, and many other such matters, and perhaps they were happier than we are today.

I object most strongly to your statement that rigid control of population growth is the solution to this problem; it opens up too many questionable aspects. If the human race is well-enough controlled in a few hundred years, or less, there won't be any humans left to use the natural resources; or maybe another

problem would be created because of the over-abundance of natural resources! I would like to see the effect on the people of the United States if they were suddenly issued an ultimatum that they could only have two children—or three children, and no more. What would be their punishment if they failed to obey this mandate?

I think you yourself have unknowingly given the answer to your question in your article; i.e. "greater intelligence in the management of our natural resources and a better public understanding of the dangerous consequences of the misuse of lands, forests, and minerals." I also feel that the old platitude "necessity is the mother of invention" is applicable in this case. If situations did not sometimes arise where something *had* to be done, civilization would be at a standstill. Scientists everyday are discovering new, beneficial materials; I use radium and penicillin as two examples. At this rate, within a certain period of time, we can reasonably expect a solution to the problem of decreasing natural resources. I don't think that there is any deadline to be met—I have never seen quoted the specific number of years that our natural resources will hold out. . . .

PATRICIA E. CARDWELL
Chicago, Illinois

Dear Sir:

The United States of America is essentially a Christian country. Its Constitution is based upon Christian Principles. The "four freedoms" of which we are so proud are basically Christian ideals. Can, then, one of these freedoms be used as an argument against a Christian Principle?

Is it for you or me to say that our natural resources are exhaustible? The world has existed for thousands of years and its resources have not become exhausted as yet.

Is the conservation of our natural resources more important than the propagation of the human race? Are natural resources more important to God than human lives? I think not.

The fact that in the past man's ingenuity has served its purpose in the conservation program is proof that man is superior in being to all other natural creatures. All these others were made to *serve man*. Now, to preserve and to conserve our natural resources must man be sacrificed? Must man serve them?

MARY JANE DOUGHERTY
Chicago, Illinois

New Members

At the meeting of the Executive Committee held on April 8, 1948, at the office of The Electrochemical Society, Inc., 235 West 102nd Street, New York City, the following were elected to membership:

STEPHEN J. ADAMS, mailing add: Wolverine Tube Division, 1411 Central Avenue, Detroit 9, Michigan (Electrodeposition, Theoretical Electrochemistry, and Corrosion)

JACQUES ALIESCH, mailing add: Leclanche S. A., 48 Avenue de Grandson, Yverdon, Switzerland (Battery)

MAURICE F. H. ANGLEYS, Societe d'Electrochemie, d'Electrometallurgie & des Acieries Electriques d'Ugine, mailing add: Premont-Orelle, Savoie, France (Industrial Electrolytic)

JAKKARAJU BALACHANDRA, mailing add: Department of Metallurgy, Indian Institute of Science, Bangalore 3, India (Electrodeposition and Electrothermics)

HENRI BURGUBURU, Societe d'Electrochemie, d'Electrometallurgie & des Acieries Electriques d'Ugine, mailing add: 10 rue du Plat, Lyon (Rhone), France (Industrial Electrolytic)

HERBERT K. DE LONG, mailing add: Magnesium Laboratories, Dow Chemical Company, Midland, Michigan (Electrodeposition)

HERBERT P. DENGLER, Columbia University student, mailing add: Box 91, Wantagh Avenue, Wantagh, L. I., New York (Corrosion, Electrodeposition, and Theoretical Electrochemistry)

N. R. FASKEN, mailing add: c/o Shawinigan Water and Power Company, P. O. Box 40, Shawinigan Falls, Que., Canada (Battery, Electrothermic, and Industrial Electrolytic)

FRANCOIS GALL, Societe d'Electrochemie, d'Electrometallurgie & des Acieries Electriques d'Ugine, mailing add: 20 rue de Bethune, Le Chesnay (Seine & Oise), France (Industrial Electrolytic)

ANDRE GANGUIN, Societe d'Electrochemie, d'Electrometallurgie & des Acieries Electriques d'Ugine, mailing add: Le Day., (Vaud), Suisse, France (Industrial Electrolytic)

HARRY HANSON, Chrysler Corporation, mailing add: 15359 Sorrento, Detroit 27, Michigan (Electrodeposition)

ROBERT S. JANE, mailing add: c/o Shawinigan Chemicals Ltd., 600 Dorchester Street W., Montreal, Canada (Electrothermic and Industrial Electrolytic)

ALFRED C. LAVALLEE, mailing add: National Carbon Company, Inc., St. Albans, Vermont (Electrodeposition)

C. ROGERS MCCULLOUGH, mailing add: c/o Monsanto Chemical Company, 1700 S. Second Street, St. Louis, Missouri

ADRIANO MONTANARI, Metalurgica Fracalanza, mailing add: Rue Maria Marcolina 103, Cidade de Sao Paulo, Estado de Sao Paulo, Brazil, South America (Electrodeposition, Electro-Organic, Industrial Electrolytic, and Theoretical Electrochemistry)

MEIER SADOWSKY, mailing add: Philco Corporation, Lansdale Tube Plant, Lansdale, Pennsylvania (Electrodeposition, Electronics, Corrosion, and Theoretical Electrochemistry)

MASSOUD SIMNAD, mailing add: Metals Research Laboratory, Carnegie Institute of Technology, Pittsburgh, Pennsylvania (Corrosion, Industrial Electrolytic, and Theoretical Electrochemistry)

A. PAUL THOMPSON, mailing add: The Eagle-Picher Company, Joplin, Missouri (Theoretical Electrochemistry, Batteries, Corrosion, Electrodeposition, Electrothermics, and Electronics)

Reinstatement

JOSIAH WORK, mailing add: 1109 So. Bronson Avenue, Los Angeles 6, California (Corrosion and Electrothermic)

Employment Situations

Please address replies to box shown, c/o The Electrochemical Society, Inc., 235 W. 102nd St., New York 25, N. Y.

Positions Available

METALLURGIST, for research on various phases of the electrolytic reduction of aluminum. Prefer advanced degree in physical chemistry or electrochemistry and/or five years' industrial experience. Location Washington. *Reply to Box A-211.*

ELECTROCHEMIST: A progressive organization requires either an electrochemist or a chemical engineer who has experience with graphite anodes in the caustic chlorine field. Must be capable of performing development and sales service. *Reply to Box A-212.*

ELECTROCHEMIST, B.S. or M.S., two years' industrial experience or more, age up to 30, for research and development work on storage batteries. Please submit résumé with salary desired. *Reply to Box A-213.*

Positions Wanted

RECENT, PH.D. in Chemical Engineering, Johns Hopkins University, desires position specializing in research or development work. Two years' chemical engineering experience with Chemical Warfare Service prior to receiving doctorate degree. *Reply to Box 330.*

METALLURGIST, research and development experience in application of electrolytic leaching and furnace methods to production and refining of non-ferrous metals including copper, lead, zinc, tin, cadmium. College degree. *Reply to Box 331.*

POWDER METALLURGIST, production, development and research. Nine years' experience platinum and precious metal powder alloys. Fifteen years' production and quality control in tungsten and molybdenum refractory metal products. Graduate course in powder metallurgy. B.S. Sc. in chemical engineering, University of Toronto, 1923. *Reply to Box 332.*

Recent Patents

Selected for electrochemists by Fred. W. Dodson, Chairman of the Patent Committee, from the Official Gazette

January 25, 1949

Briggs, T. H., Jr., 2,459,789, Electrode Construction for Neon Signs.

Stateman, M. J., 2,459,848, Rectifier Element.

Stateman, M. J., 2,459,849, Testing Circuit.

Krok, W. P., 2,459,886, Selenium Rectifier.

Richards, L. M., 2,460,105, Photopolymerization of Vinylidene Compounds With Organic Disulfides.

Slade, H. B., 2,460,107, Apparatus for Testing Insulated Wire and Cable.

Du Rose, A. H., and Little, J. D., 2,460,252, Lead-Tin Alloy Plating.

February 1, 1949

Lohr, J. M., 2,460,590, Electric Resistance Element and Method of Heat-Treatment.

McBee, E. T., and Pierce, O. R., 2,460,705, Chlorinolysis.

continued on page 136c

Feature Section

The Profession of Electrochemistry

V. Opportunities in the Primary Battery Field

George W. Heise

The primary battery, first described by Volta almost 150 years ago, is the oldest, and commercially one of the most important of our electrochemical products. Few technical fields present greater opportunities to the electrochemist, are more diversified, or offer greater challenge to his research ability, manipulative skill, and inventiveness.

The industry itself is larger than is generally recognized. For a long time the battery was the only available source of direct current, and even after the introduction of dynamo-electric machinery, a continuous stream of new applications such as telegraph, telephone, door-bell and annunciator, flash light, ignition and, more recently, radio and various forms of electronic devices served to maintain an ever-increasing demand for batteries, particularly of the portable types. In the U. S. A. the manufacture of Leclanché type dry cells alone, about two million units per year at the turn of the century, rose to a peak rate of over three billion during 1945, the last year of World War II, and is probably not far from two billion at the present time. Several million wet cells, mostly of the copper oxide or air-depolarized types, ranging in size up to 1,000 ampere hours, are produced annually, largely for railway signaling and similar services. In recent years several new types of batteries have been marketed which promise to achieve real commercial significance.

Concurrent with the expansion of the industry, battery technology has shown a gradual transition from an art to a science. Important improvements have been realized, in construction, manufacturing methods, and above all in quality, and the usefulness of batteries has been extended over a wider range of operating conditions. A standard "D" size flashlight cell can now be made of as great an energy output as the 6-inch unit of 35–40 years ago. Much has been learned of the basic reactions operative during battery discharge and their interdependence; better understanding of the factors involved in cell deterioration has greatly improved shelf life; new anode, cathode, and electrolyte materials are coming into use. Yet the work done has served to widen our horizons and to indicate how much more remains to be accomplished rather than to narrow the field of productive investigation.

GEORGE W. HEISE

The marked upsurge in interest in batteries, particularly noticeable during the past ten years, has meant a great increase in technical work, not only by the laboratories directly serving the industry itself, but also by colleges and government agencies, thereby creating more opportunities for the electrochemical aspirant in this field.

Finally, it should be emphasized that the interests of the technologist extend far beyond the commercial batteries of today. A successful fuel cell, as made possible by the use of gas electrodes, for example, should permit the liberation of electrical energy at several times the efficiency attainable by ordinary combustion methods. The introduction of

suitable anodic or cathodic depolarizers is capable of increasing the efficiency and reducing the power requirement of many electrolytic reactions, organic as well as inorganic. The indications are that for a long time to come, the electrochemist, especially if equipped with the newer techniques, will find battery work a fertile field for his activities, and one offering rich intellectual rewards, whether he selects the "pure science that sets the stage for technology" or devotes his efforts to applied research and development.

Technical Notes and Reviews

The Use of Fluorescent Dyes as Tracers in Biology and Medicine*

Kurt Lange†

While the use of radioactive tracers in biology and medicine has received considerable attention during the last few years, the somewhat older method of using fluorescent tracers in the same fields has been pushed slightly into the background. Although both methods have their distinct fields of application, advantages and disadvantages, one can occasionally notice that radioactive tracers are being used where fluorescent substances would give more clear-cut results and would be much simpler to use. It is the purpose of this paper to attract the attention of physicists and electrochemists to the possibilities and to create a collaboration with the physicians working in the field.

Fluorescein in Ophthalmology

As early as 1882 Paul Ehrlich (1) introduced the use of fluorescein (resorcinol phthalein) for the study of the origin and flow of the fluid in the anterior chamber of the eye. By injecting fluorescein intravenously in rabbits, he studied its appearance in the eye and its way through the eye under incandescent light. This was followed by a great number of papers in the ophthalmologic literature dealing with this highly important problem, using the method of detecting the flow of the liquids in the eye by "tagging" the serum with fluorescein. In these studies, it soon became apparent that we are not really "tagging" the watery phase of the blood by these methods, but that fluorescein migrates with the blood and leaves the vascular tree through the semipermeable capillary walls according to its own laws (gradients, permeability of the wall, partial pressure) and quite independently of and occasionally in the opposite direction to the flow of water in and out of the vessels.

Approximately at the same time, fluorescein was used for the first time to detect small lesions in the cornea, the surface membrane of the eyeball. The intact cornea when wet with a fluorescein solution will not retain any of the dye which is eliminated rapidly with the tear fluid. If the surface membrane is broken, however, the tissue at the denuded area is stained by the dye and, under long wave ultraviolet light, the small lesions which are otherwise hard to detect can be seen clearly.

While these studies found great interest in ophthalmologic circles, other fields of medicine and biology did not make any use of these techniques until 1929 when Hirt and Ellinger (2) started the use of different fluorescent dyes to study the excretory apparatus of frogs' kidneys by direct microscopic observation under long-wave ultraviolet light. They were able, by using alkaline and acid fluorescent dyes, to study the behavior of different parts of the kidney and the liver.

Stimulated by these studies, we succeeded in 1931 for the first time in making the dye fluorescein visible in the

* This paper was presented at the Symposium on Luminescence, held at the Philadelphia Meeting, May 6, 1949.

† From the Department of Medicine, New York Medical College, Flower and Fifth Avenue Hospitals and the New York Medical College Research Unit (Metropolitan Hospital).

human capillaries of the lips and conjunctiva after an intravenous injection. We initially used a carbon arc lamp with filters which had a narrow band of transmission having a peak near 3800 Angstrom units. After the appearance of the mercury vapor reflector bulbs with high spot intensity (General Electric CH4) and the fitting Rondell filters of Corning glass 587, the carbon arc was abandoned. It must be mentioned here that the construction of a less expensive and lighter unit with approximately the same emission characteristics would be highly desirable and that there would be a considerable interest in such a lamp in medical circles for many diagnostic procedures.

Measuring Blood Circulation Time

With this method of direct visualization of fluorescein in the blood stream of the lips, we were able to devise an *objective* method of determining the speed of blood flow from the point of injection to the point of detection. Before that, only subjective methods had been used for this diagnostically highly important purpose. By injecting substances which produced a sweet or bitter taste upon their arrival at the taste buds of the tongue, one was able to determine the circulation time. These methods have the drawbacks that they can not be used in children or unconscious persons, that the threshold of the sensation of taste for these substances shows considerable individual variations, and that certain commonly used drugs alter this threshold considerably.

With the use of the fluorescein method, which is extremely simple, the early detection of heart failure, of certain disturbances of the function of the thyroid gland, of beginning shock (4), and of certain types of congenital heart anomalies is possible (5). In addition, the results of therapy in these diseases can be more readily gauged by this method. The examination consists in directing the light of one of the long-wave ultraviolet lights onto the patient's lips in a slightly or completely darkened room and observing the time which elapses between the injection of the 5 per cent fluorescein solution into a vein on the arm and the sudden striking appearance of a green color of the lips. Using this method it was found that the circulation time is very constant in normal individuals. Studies in infants and children (6, 7) have shown that the circulation time in children is considerably faster and decreases with advancing age to come to the rather constant value of 13–17 seconds in the adult.

Since it could be demonstrated that fluorescein has an extermely low toxicity, we were able to increase the amount injected to such an extent that it becomes visible in the intact skin. After the circulation time has elapsed, the skin and all mucous membranes assume a green color clearly distinguishable from the purple color before the injection under the ultraviolet light. This color results from the dye which diffuses out of the vascular tree into the interstitial space and cannot be decreased by pressing a glass spatula on the area of observation, a procedure which leads to an emptying of the capillaries themselves. Since this diffusion continues until no gradient exists between the content of free fluorescein in the serum and that of the interstitial fluids, an increasing staining can be observed for about 20 minutes until equilibrium is reached.

Fluorescein is present in the blood stream only to a small percentage as the free dye while the rest (70–80%) is bound to the proteins of the blood. In the ranges of physiologic variations of the blood proteins, this tie-up is practically constant for the different protein concentrations which occur (Fig. 1). Since only the free fluorescein diffuses out into the tissue and since the fluorescein tied to the proteins does not emit any fluorescence, this tie-up is of great importance. It can be completely broken, however, by alkalinization of blood or body fluid samples to a pH of 10.

The Dermofluorometer

In order to measure objectively the degree of fluorescence obtained over different parts of the body an instrument was devised (8) which represents a colorimeter directly applied to the skin. The Dermofluorometer (Fig. 2) consists of an overvoltaged incandescent light source which shines from a constant distance through a blue filter of Corning glass #5113 on the skin to be examined. Rigidly aligned to it is a phototube which, by a yellow filter #3486, picks up only the green light resulting from the fluorescence after the injection and registers through an amplifier the intensity of the fluorescence. The instrument is calibrated before each test

against a standard fluorescein solution and thus permits objective comparisons between the reaction of different individuals and the same individual under different conditions.

Several factors, of which capillary permeability is one of the most essential, influence the speed of diffusion of the dye; thus, an area in which the capillary permeability is increased, e.g., inflammation, will show a much more rapid and intense staining than the surrounding tissue. On the other hand, tissue with a decreased blood supply, e.g., old scars, will show hardly any fluorescence.

The mucous membranes of the intestinal tract stain very intensely due to their high vascularity and great transparency.

Based on these observations numerous uses have been suggested for this method. In diseases of the blood vessels of the limbs associated with narrowing or occlusion of such vessels, the area of decreased blood supply can be clearly outlined by the diminished fluorescence prevailing therein (9). Sudden occlusion of blood vessels by blood clots can be immediately diagnosed as to completeness, extent, and possibility of other neighboring vessels taking over for the occluded one. Arteriosclerotic and diabetic gangrene can be predicted at relatively early stages of the disease when the method is used in combination with other diagnostic procedures. Ulcers of the leg due to varicose veins or inflammation of veins can be judged as to their healing tendency by the amount of fluorescence that can be detected in them after a fluorescein injection.

In the process of skin grafting the method has proved quite helpful (10).

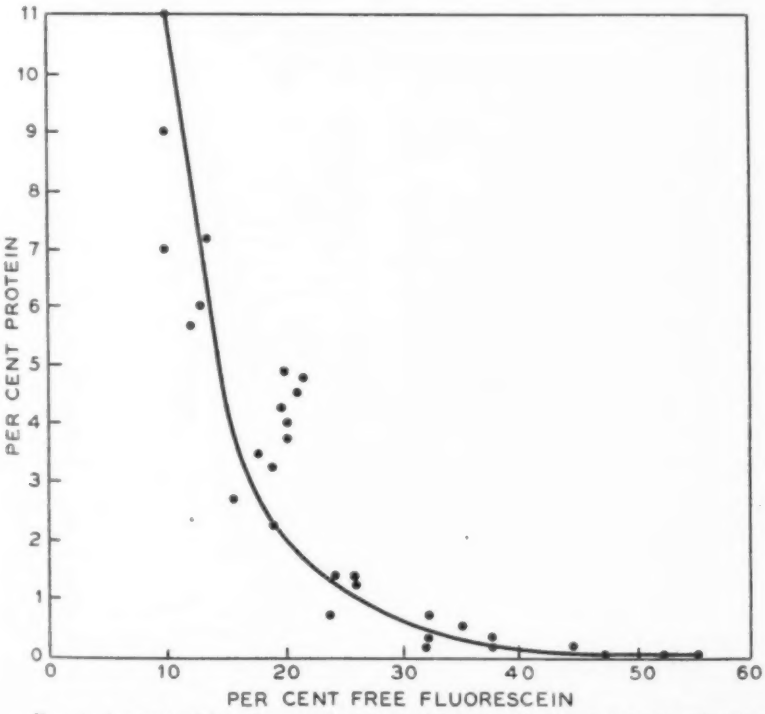

FIG. 1. Amount of free fluorescein obtained by ultrafiltration through collodion membranes from human plasma with different protein content.

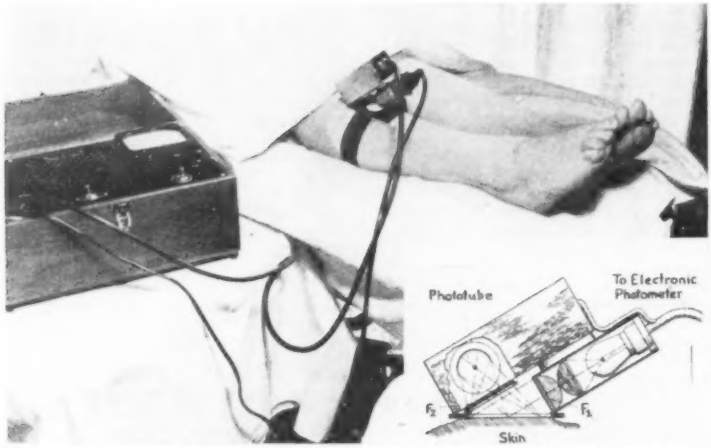

FIG. 2. The Dermofluorometer. The search unit comprising the light source and the phototube is attached to the leg of a patient. Lower right—Schematic drawing of the search unit. F1 blue filter in front of light source, F2 yellow filter in front of phototube.

Skin grafting on a non-healing site will be successful only if the bed is fully supplied with blood so as to be able to nourish the transplanted skin. A fluorescein test can clear these facts in advance and thus help to avoid pitfalls. In more complicated methods of skin grafting, the use of the fluorescein method to establish the presence of sufficient circulation has been able to shorten the length of the hospital stay considerably. Since the tests can be carried out without danger at short intervals, repeated tests show the earliest possible moment when the reestablishment of the circulation permits the next step in the operative procedure.

Surgical Uses

In treating cases of strangulated hernia, the surgeon is often confronted with the question whether the loop of gut which was for hours in a strangulation is still viable, a grave decision since chances of recovery are much worse when a part of the gut must be resected due to nonviability. By injecting fluorescein in an arm vein and shining the long-wave ultraviolet light on the loop of gut in question, the surgeon can immediately decide whether to resect or not, depending on the absence or presence of fluorescence in the part (11, 12). Many institutions have made this procedure routine in all questionable cases. Other surgical procedures on the intestine can be made safer by ascertaining with a fluorescein test that a part of gut to be resected does not contain the blood vessels supplying blood to the parts not to be resected.

Most recently the method has been used to visualize the gall bladder and especially the bile ducts during operations by their brilliant fluorescence after a fluorescein injection (13). In cases of old adhesions and inflammations of this area, there is great danger of accidentally incising the vital bile ducts when they are not clearly visible in the matted inflamed tissue.

Since areas of increased permeability of the skin show up under the test by increased fluorescence and since certain forms of allergy are associated with increased capillary permeability (wheals, hives), interesting and valuable studies were performed to evaluate the effectiveness of certain antiallergic drugs in reducing capillary permeability (14).

Since inflammations cause increased permeability of the blood vessel walls throughout the body, inflammations of the meningi, the fine membranes covering the brain and the spinal cord, are accompanied by an increased permeability of their blood vessels. An injection of

fluorescein into the blood stream yields, after a certain period of time, an increased amount of fluorescein in the spinal fluid. A simple fluorophotometer permits a quick and accurate estimation of the fluorescein content. This enables one to make or exclude at an early stage the diagnosis of certain forms of meningitis and to follow closely the success of therapeutic endeavors (15).

Applications in Dermatology

A wide variety of interesting possibilities has been opened by applying the fluorescent tracer method to skin diseases. Numerous highly interesting observations have been reported about specific pictures of fluorescence in otherwise similar-appearing forms of skin diseases. The diagnostic and therapeutic possibilities are thus greatly increased (16).

By using the fluorescein method in experimental and human frostbite it was possible to show that this lesion is associated with a tremendously increased capillary permeability and that this is the cause for the loss of the "swimming fluid" of the blood corpuscles which then silt up the capillaries forming a red cell sludge which finally leads to the dreaded gangrene. After this realization, certain therapeutic measures were suggested which have now reduced the incidence of gangrene by approximately 80 per cent (17).

Possible Application in Cancer Studies

Most recently, the suggestion has been made that cancerous tissue retains fluorescein longer after an intravenous injection than normal tissue. Thus, a diagnostic procedure would be available to distinguish, by relatively simple means, between normal and malignant tissue. Since fluorescein is not visible beyond the penetration power of the ultraviolet light, these investigators tagged the fluorescein by adding a radioactive iodine molecule to it and localizing its storage with a Geiger-Muller counter. They report that they were thus able to localize brain tumors by the retention of the radioactive fluorescein. These studies are so important that further confirmation and differentiation from closely related but benign lesions need to be awaited before they can be generally accepted (18).

Beside fluorescein, riboflavin has been used as a fluorescent tracer (19). Since both substances are quite innocuous, both may be used, but fluorescein has a much higher fluorescence per milligram and can be detected in much lower concentrations (0.5×10^{-9} %).

The presence of fluorescein in body fluids and its optical effects are subject to laws which require much further study. A shift of pH is known to shift the wavelength of the emitted light of fluorescein. One would thus be able to estimate directly the pH in tissues if an instrument were available to determine rapidly the peak wavelength of the fluorescence in different tissues. We were interested in the fact that the blood proteins (albumins and globulins) produce an intense quenching effect on aqueous fluorescein solutions. This effect is very pronounced and may be used to determine very small amounts of proteins in body fluids and possibly in other organic solutions. Unfortunately the relation of the quenching effect and the amount of protein present is not linear and becomes quite erratic at very low concentrations. A systematic collaboration between electrochemists and physicians may solve this problem of great importance in many biological questions which cannot be solved by any other method so far.

Need for New UV Light Sources

The creation of a long-wave ultraviolet light source, small and cool enough to be attached to endoscopic instruments, would enable the diagnostician to observe the different degrees and distribution of staining in body cavities and possibly lead to entirely new diagnostic applications in this field.

Numerous other possibilities are under investigation in many institutions in this country and abroad.

If the same collaboration between electrochemists and physicists on the one hand and physicians on the other could be established in the field of fluorescence as in the field of radioactivity, it is the author's opinion that tremendous advances in many fields of medicine could be made.

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Recent Patents

(*Continued from page 129C*)

February 8, 1949

Fisher, S. O., 2,460,817, Alloy Suitable for Use at High Temperatures.
Meyer, W. R., 2,460,896, Composition for Blackening Copper and Copper Alloy Surfaces.
Meyer, W. R., 2,460,897, Rendering Aluminum and Aluminum Alloy Surfaces Corrosion Resistant.
Meyer, W. R., 2,460,898, Process and Composition for Coloring Copper and Copper Alloy Surfaces.
Riggs, H. C., 2,461,002, Quick-Change Battery Support.
Clingan, I. C., 2,461,035, Electrolytic Stainless Steel Polishing.
Clingan, I. C., 2,461,036, Stainless Steel Polishing.
Sell, R. G., and Thompson, L. E., 2,461,087, Alternating Electric Current Rectifier of the Dry Surface Contact Type.
Flinspach, M. L., and Flinspach, J. H., 2,461,111, Soil Moisture Indicator.
Cass, O. W., 2,461,142, Production of Beta-Trichlorethane.
Jones, T. C., 2,461,325, Electrolytic Water Purifier.
Schaefer, R. A., and Mohler, J. B., 2,461,350, Electrodeposition of Lead-Antimony-Tin Alloys.
Clark, R. U., 2,461,410, Porous Electrode for Electrolytic Cells.

February 15, 1949

Gray, A. G., Gresham, W. F., and Loder, D. J., 2,461,507, Electrodepositing Composition and Process.
Chace, P. G., 2,461,518, Corrosion-Resisting Thermostat Metal.
Ellis, G. B., 2,461,534, Leak Resistant Electrical Cell.
Lorig, E. T., 2,461,556, Method and Apparatus for the Electrolytic Coating of Metal Strip.
McConnell, C. H., 2,461,752, Storage Battery Holder.
Chester, A. E., and Reisinger, F. F., 2,461,809, Zinc Electroplating.
Greig, H. G., 2,461,892, Electrolytic Recording.
Smith, P. T., and Smith, J. A., 2,461,933, Rhodium Alloy Coatings and Method of Making Same.
Stockdale, J., and Rison, D. E., 2,461,935, Insulated Electrical Resistances.

February 22, 1949

Oakes, L. F., 2,462,125, Electrophoretic Coating of Metal Articles.
Blackburn, W. E., 2,462,157, Method of Eliminating Porosity in Crystalline Selenium Films.
Jernstedt, G. W., 2,462,197, Etching Method.
Wallhausen, C. W., and Dooley, H. H., 2,462,241, Radioactive Metal Products and Methods of Making Same.
Bludworth, J. E., Robeson, M. O., and Truby, H. A., Jr., 2,462,301, Electrolytic Production of Allyl Alcohol.
Akin, F., 2,462,453, Battery Terminal.
Leverenz, H. W., 2,462,517, Method of Manufacture of Luminescent Materials.
Pithia, J. J., and Ward, R., 2,462,547, Doubly Activated Infrared Phosphors and Methods of Preparing Same.
Terry, B. F., 2,462,570, Method of Forming Printing Plates.
Dubpernell, G., 2,462,615, Method of Chromium Plating and Treating Steel Airplane Propeller Blades.
Moore, J. C., 2,462,660, Battery Cable Clamp.
Olcott, E. L., 2,462,665, Alloy.
Percy, J. H., 2,462,669, Process and Apparatus for Photocatalytic Reactions.
Detrick, S. R., Lockwood, W. H., and Whitman, N., 2,462,730, Preparation of Polysulfonyl Chlorides.